

Large-Scale Circulation: Three Big Ideas

1) Meridional Temperature and Momentum Transport (Mean Meridional Circulation)

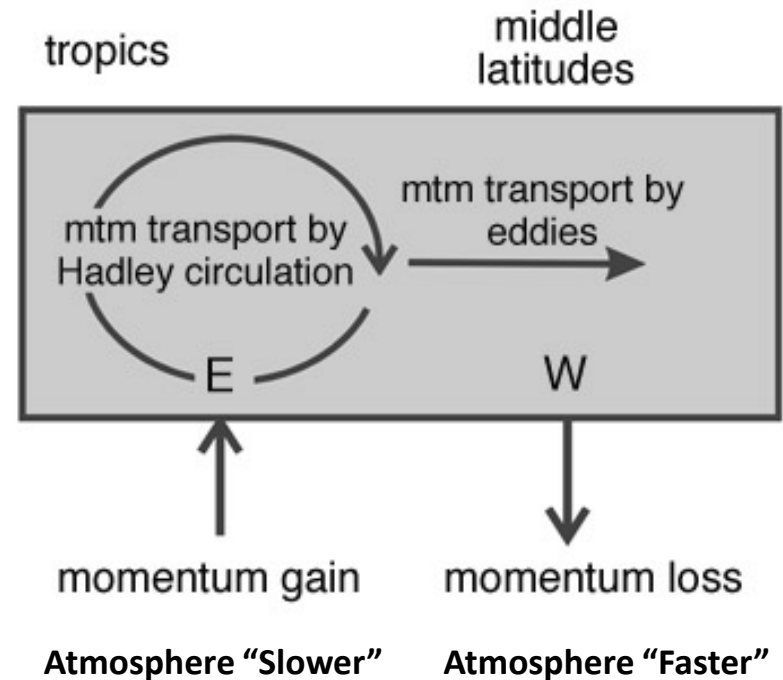
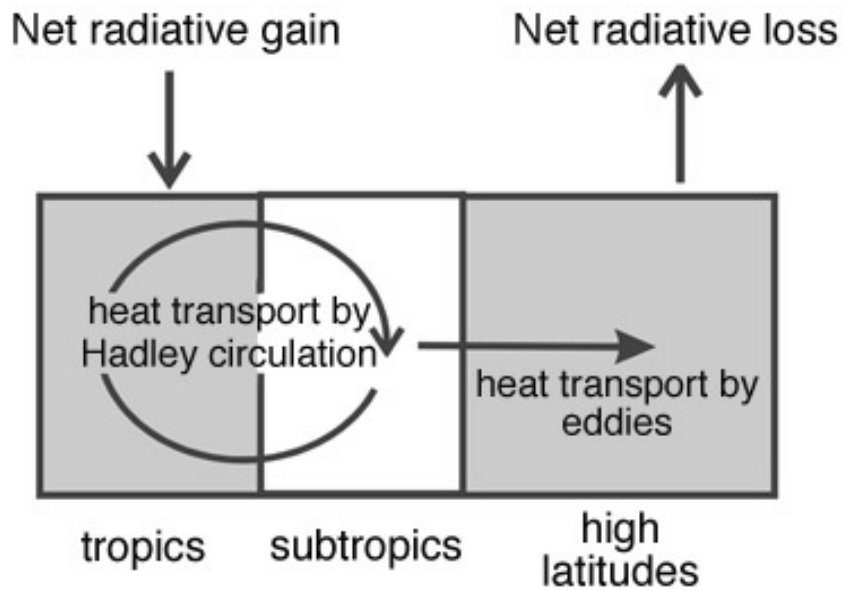
- Stationary and Transient Eddies

2) Large-Scale Tropics

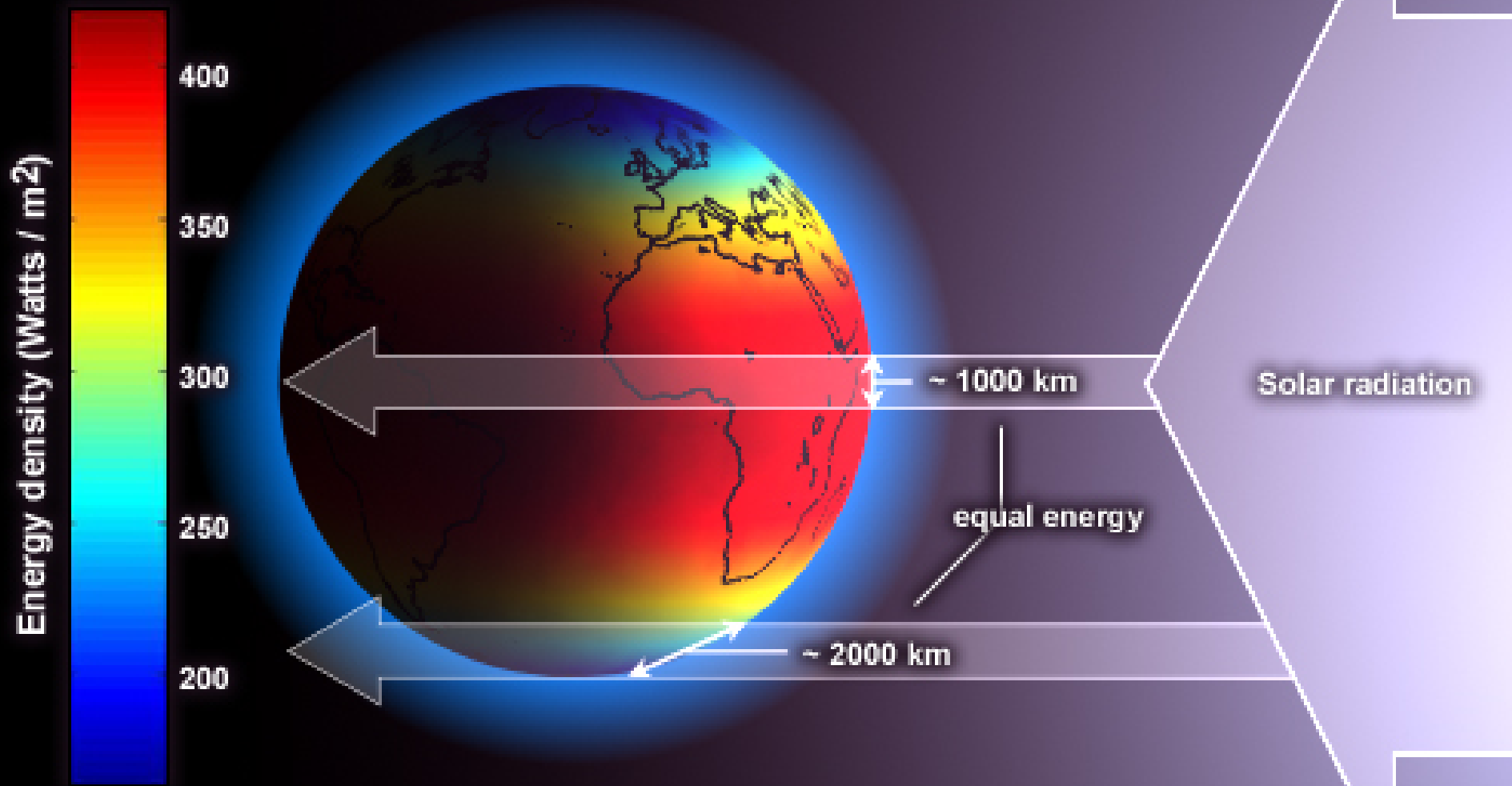
- ENSO

3) Climate Change

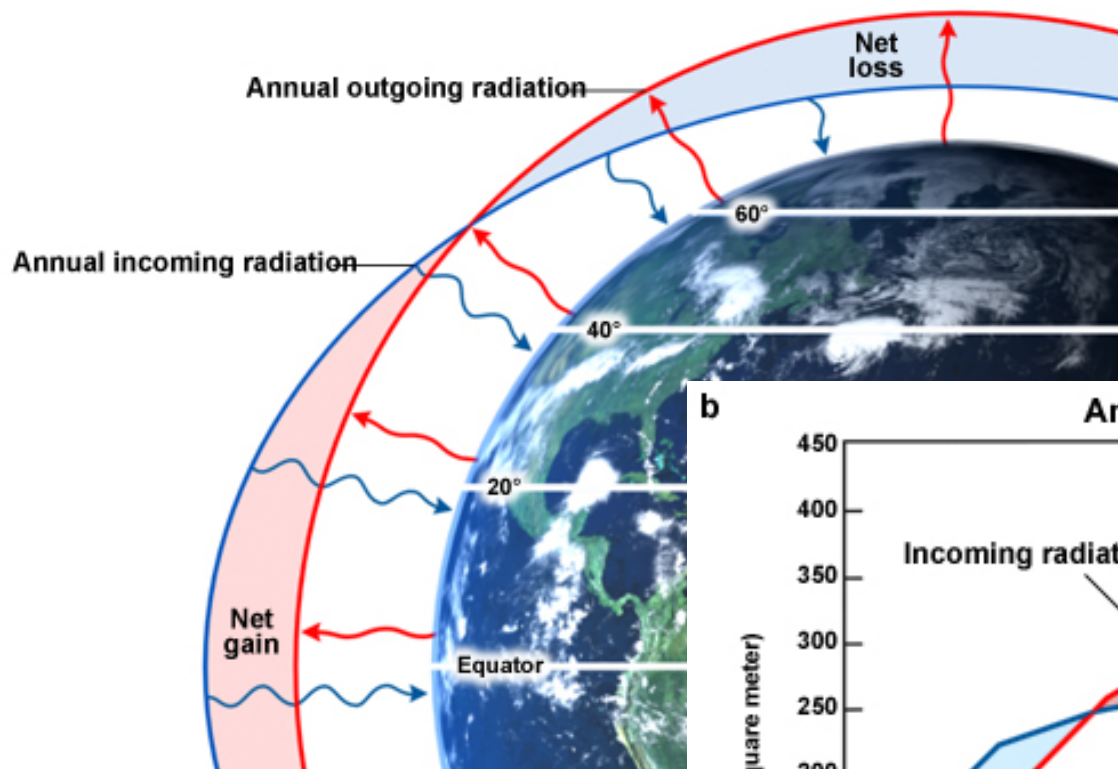
1) Meridional Temperature and Momentum Transport



Mean Annual Global Insolation

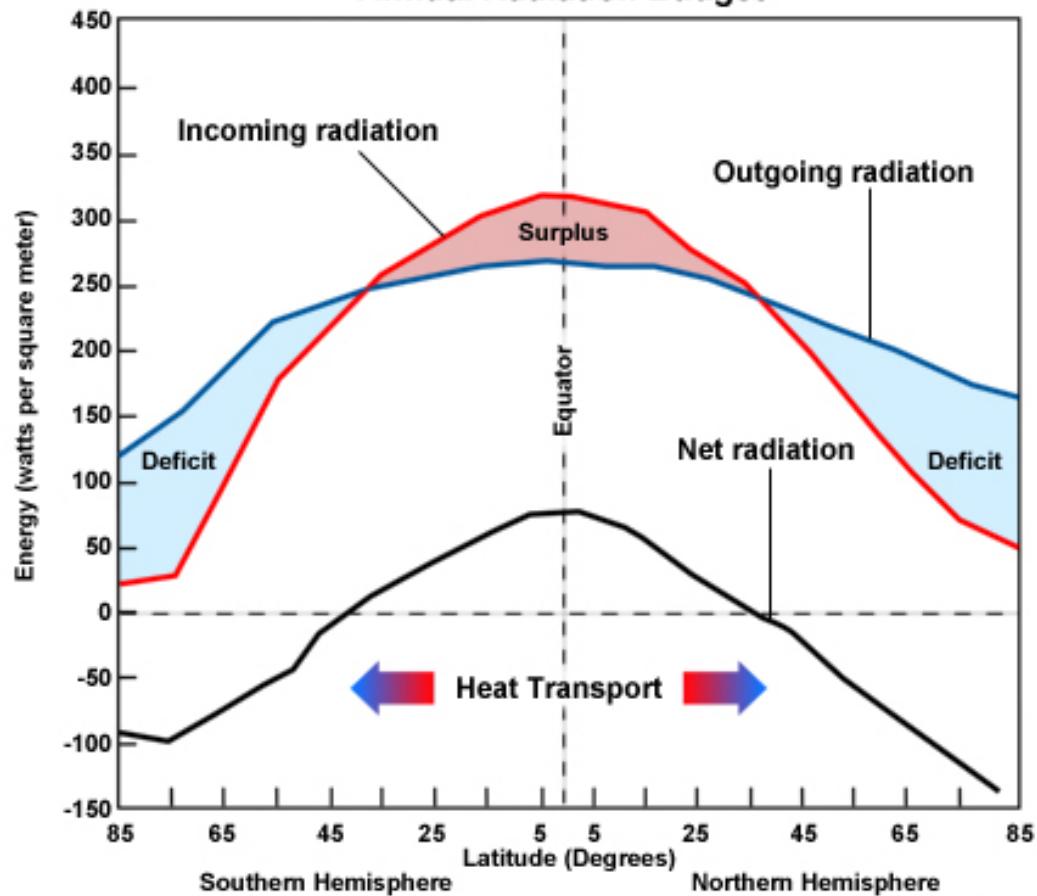


a

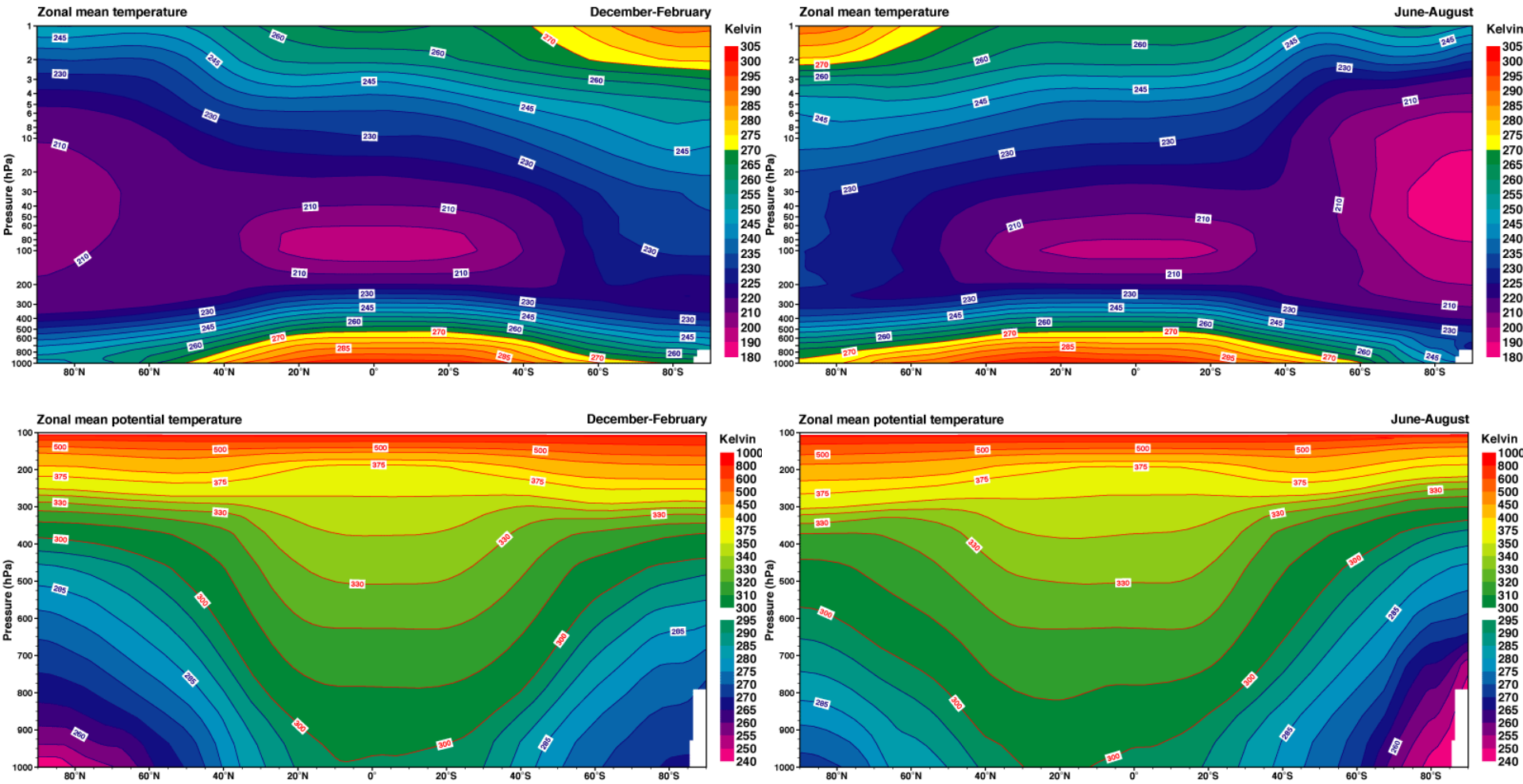


b

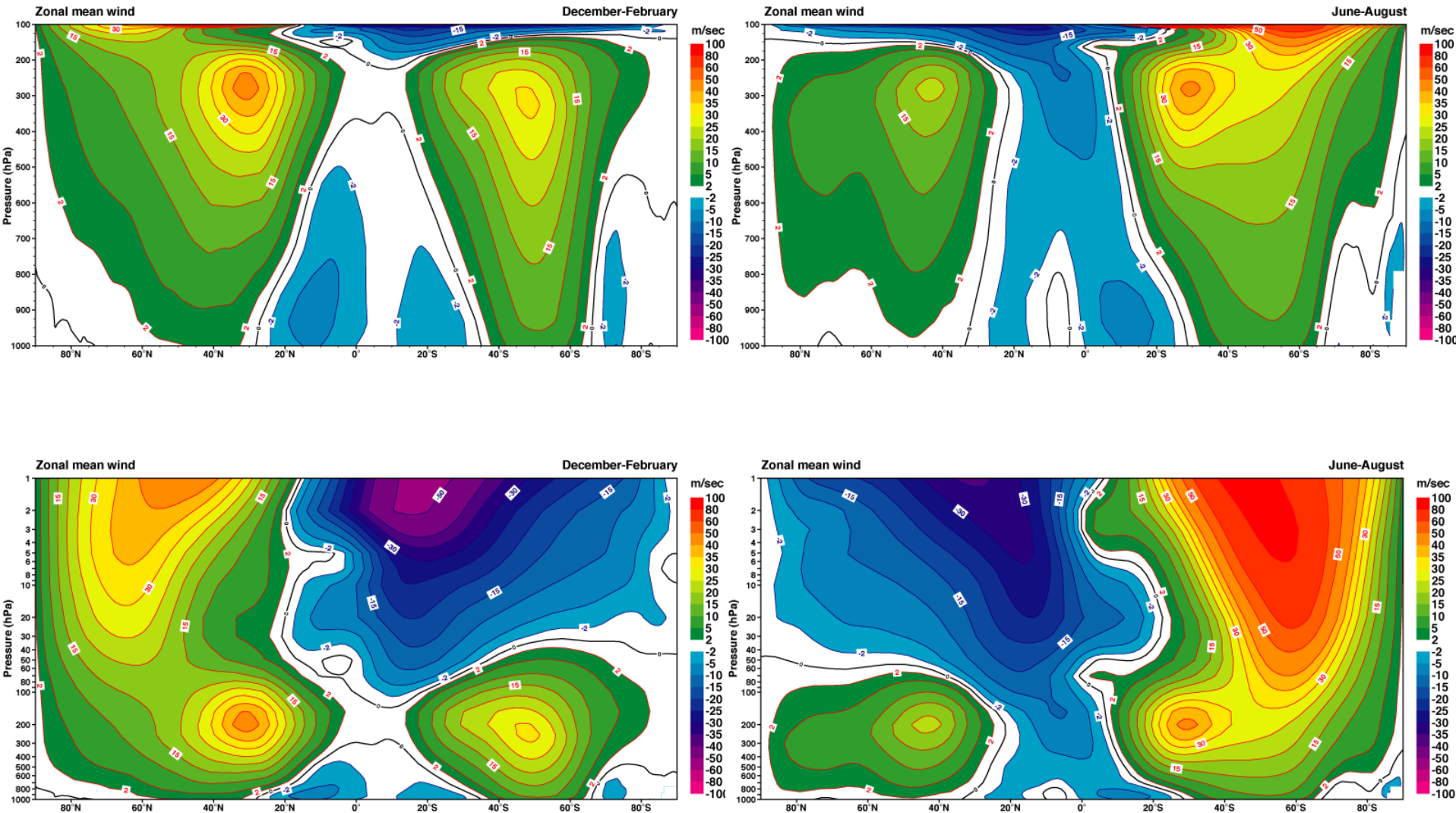
Annual Radiation Budget



Temperature and Potential Temperature Structure of the Atmosphere



Zonal Wind Structure of the Atmosphere

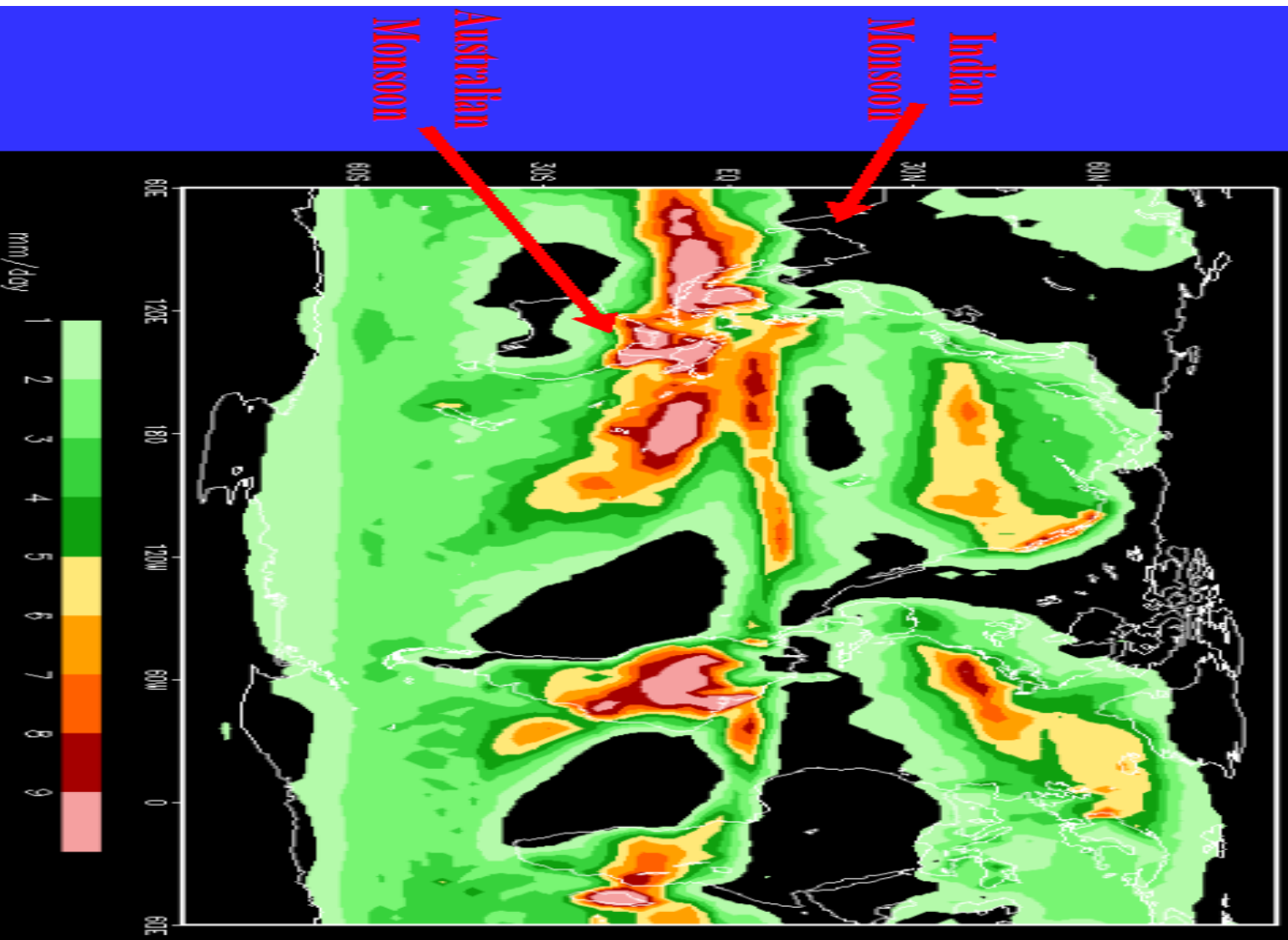


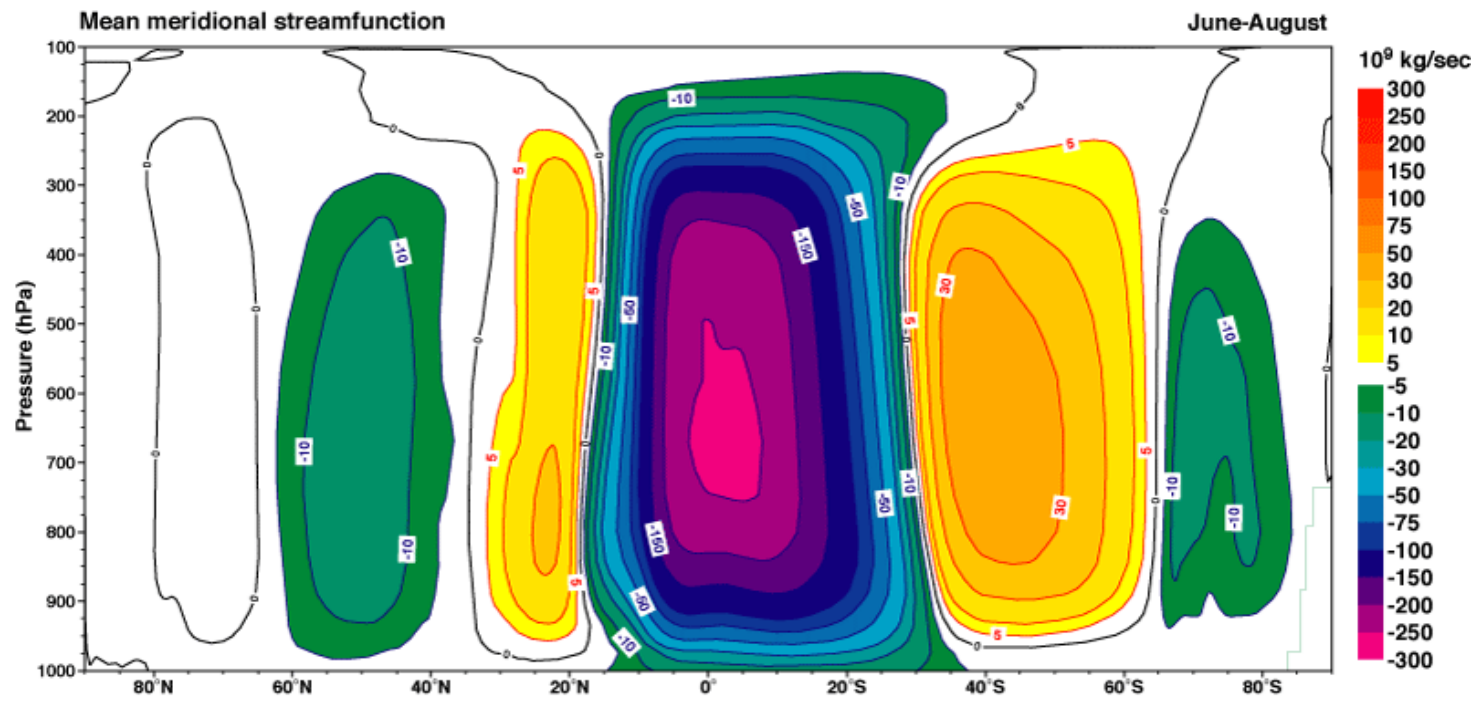
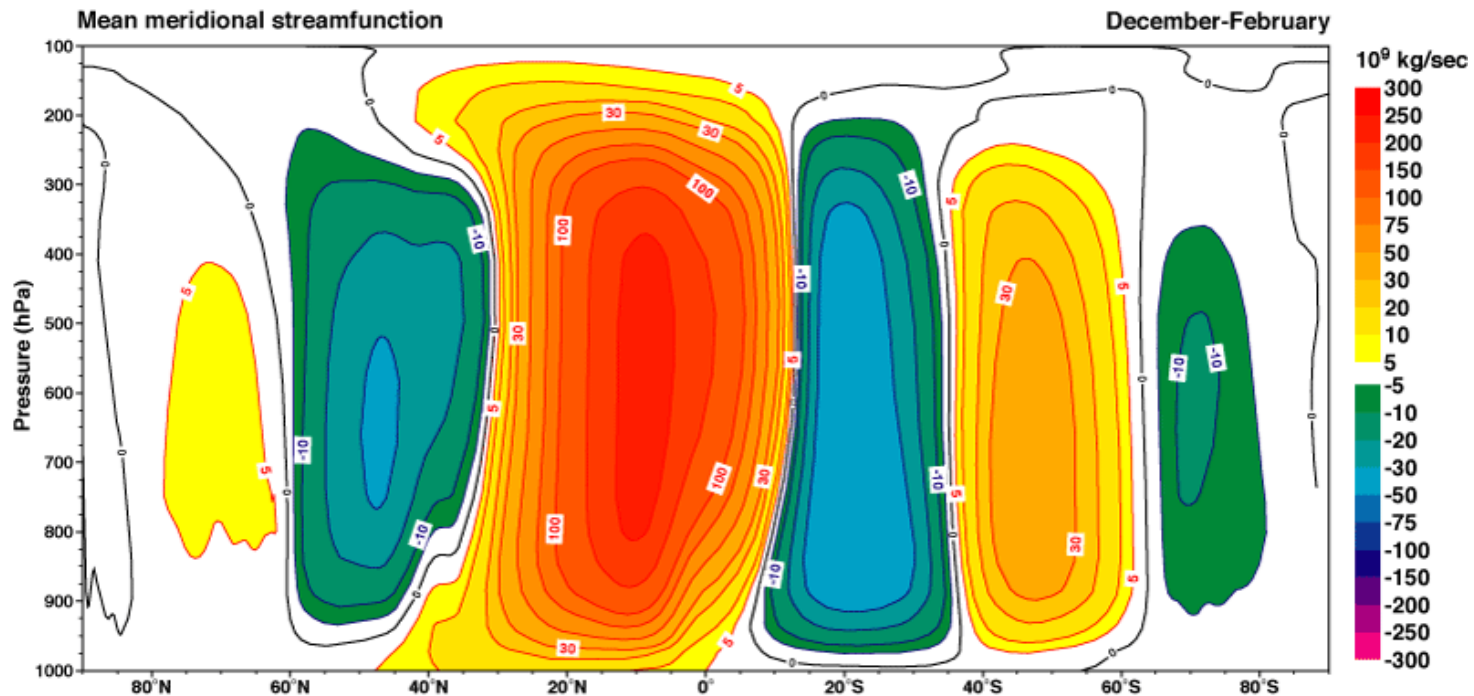
ITCZ Intertropical Convergence Zone

- Latitude of Tropical Precipitation Maximum
- Not Necessarily Latitude of Maximum Rising Motion

(from IR1)

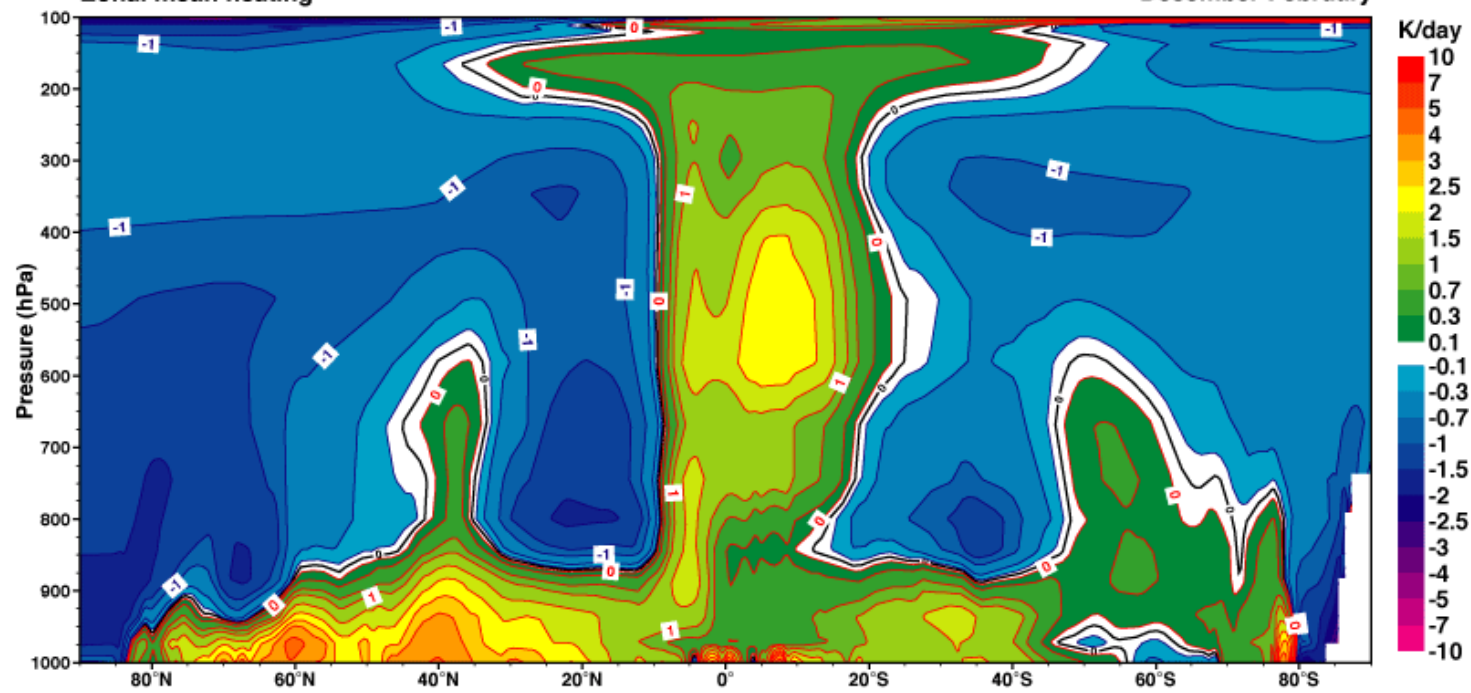
Mean Jan GPCP Precipitation (79-03)





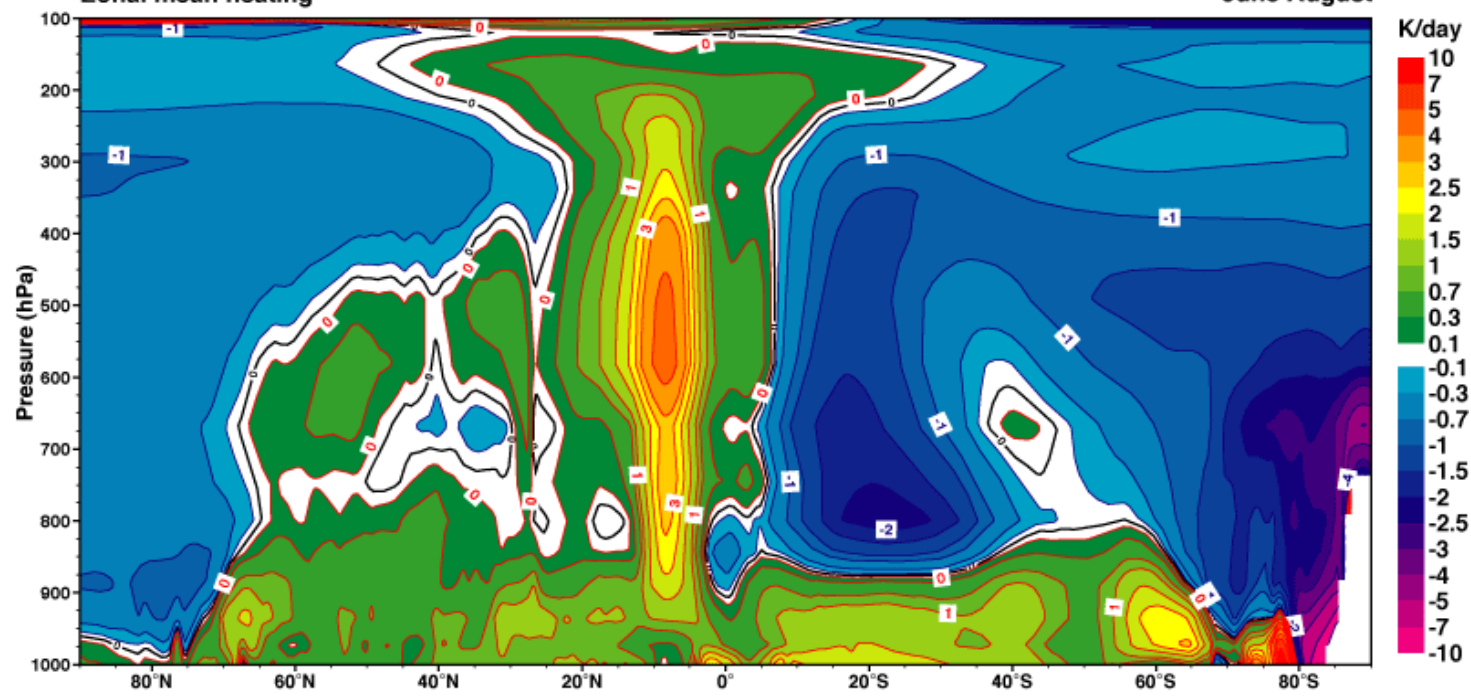
Zonal mean heating

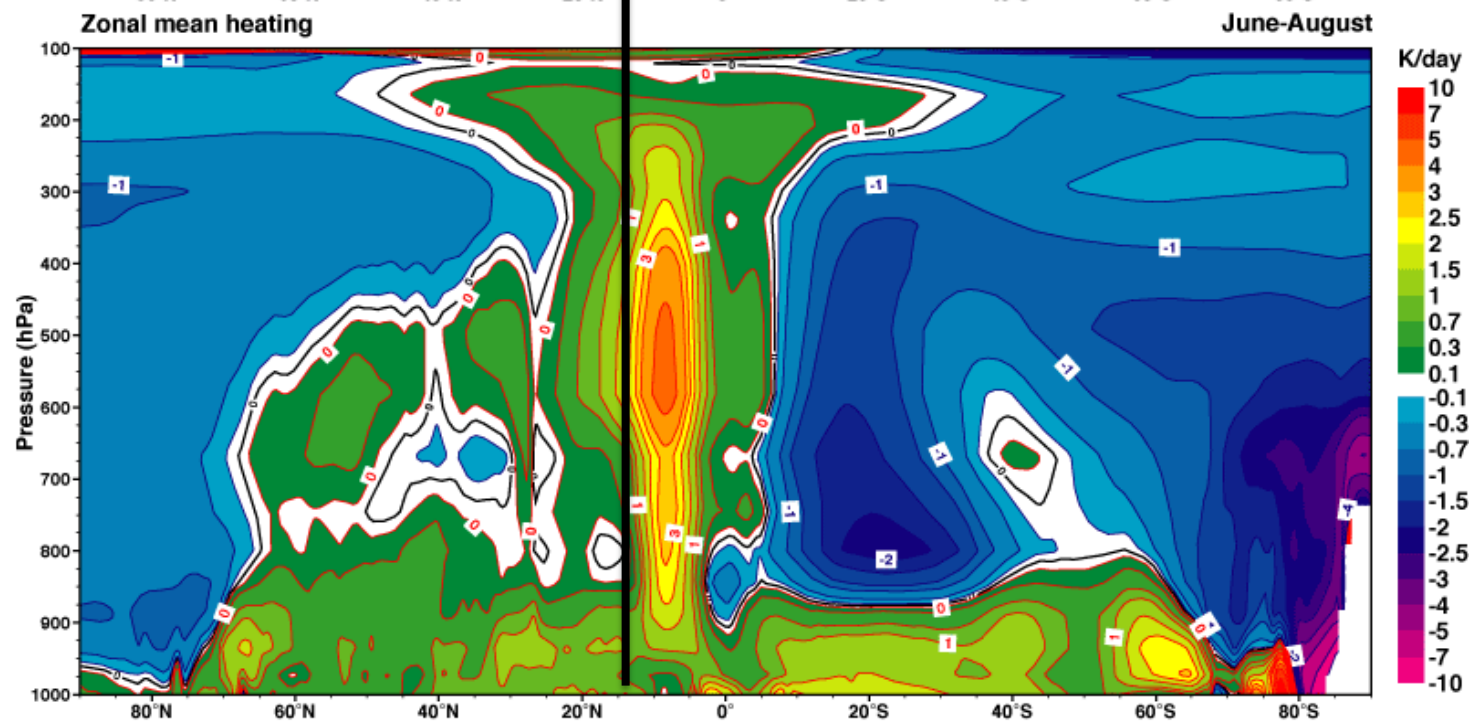
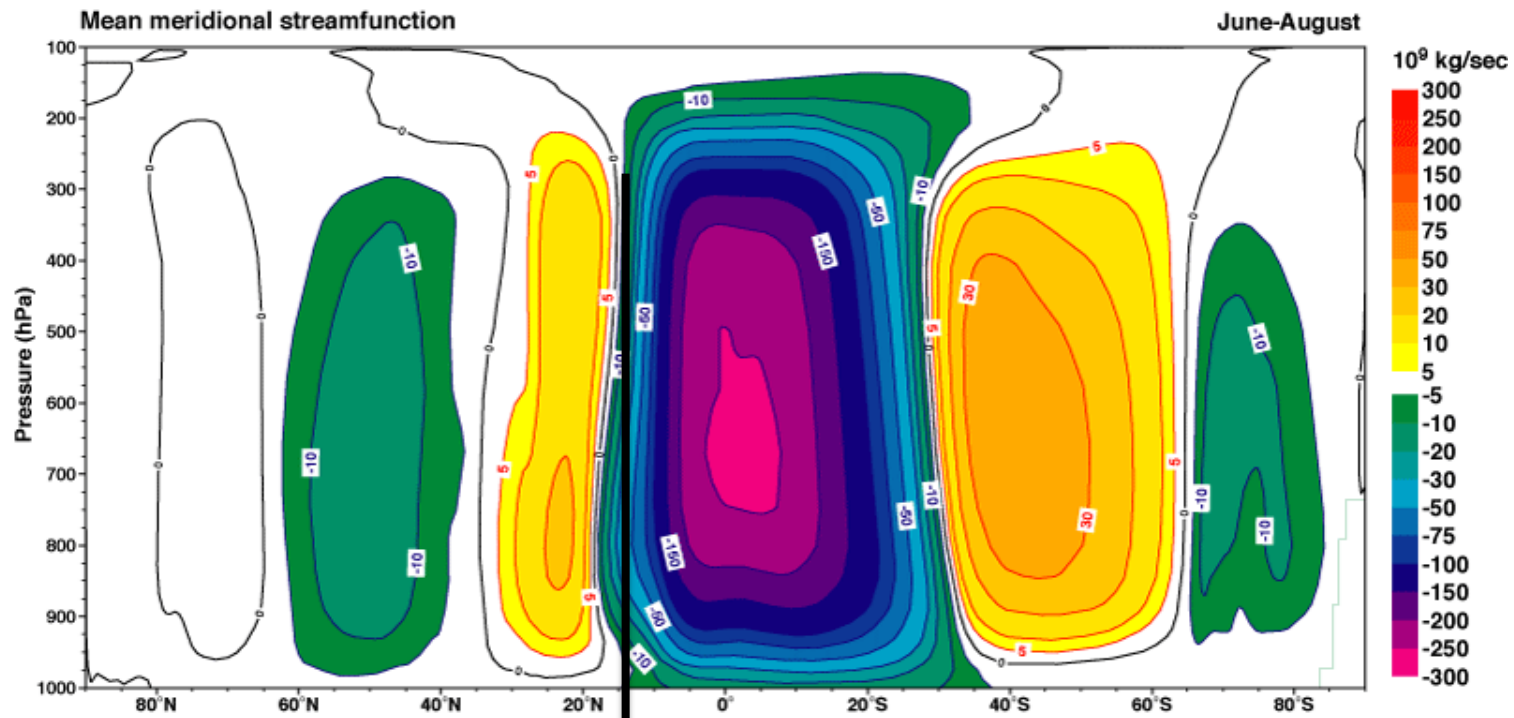
December-February



Zonal mean heating

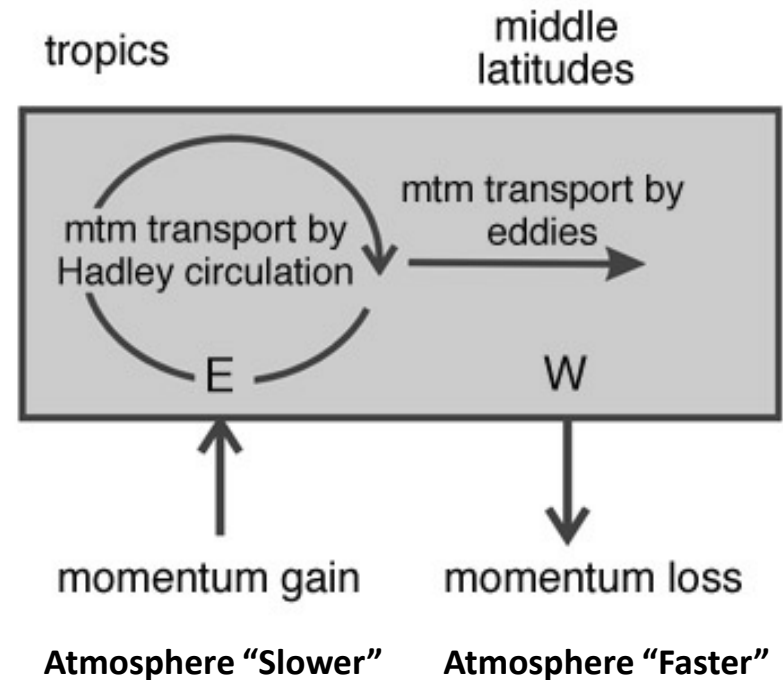
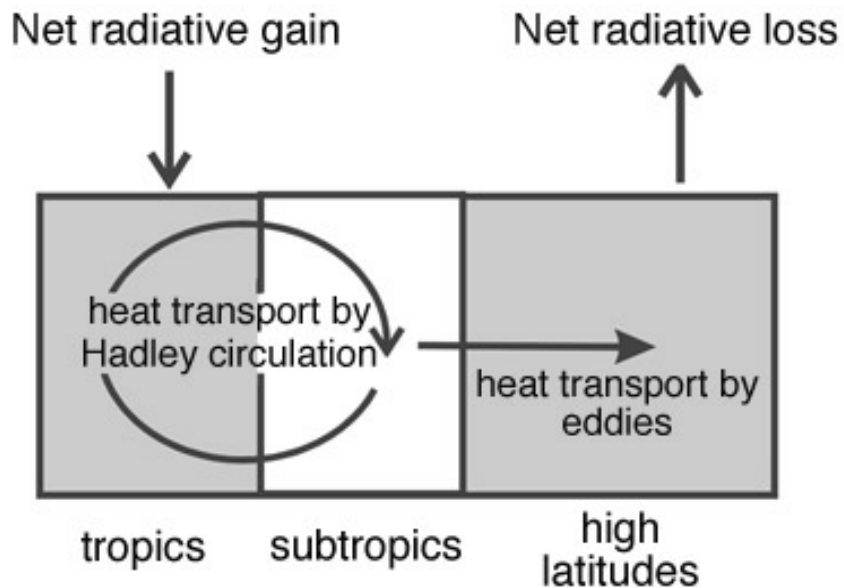
June-August

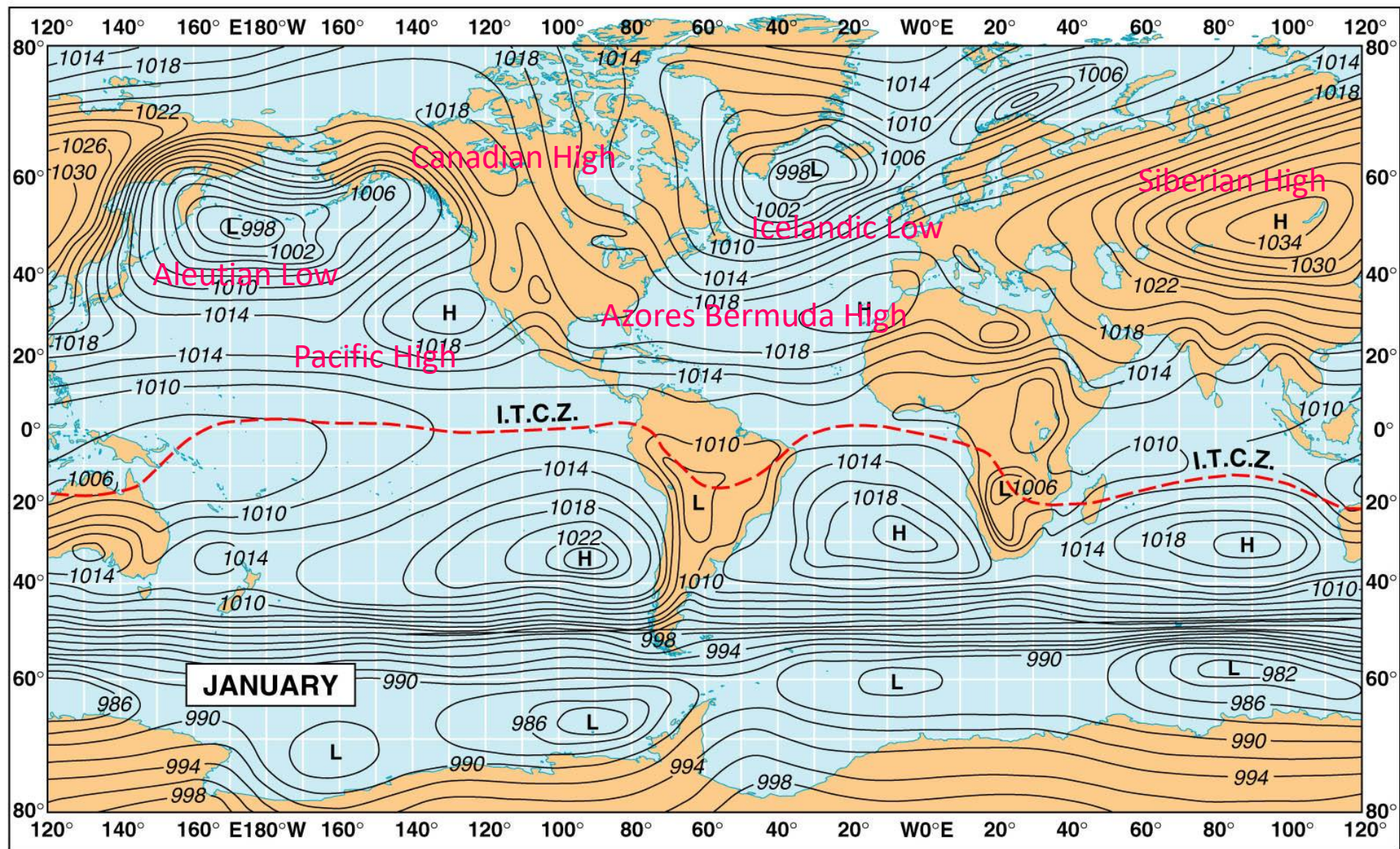




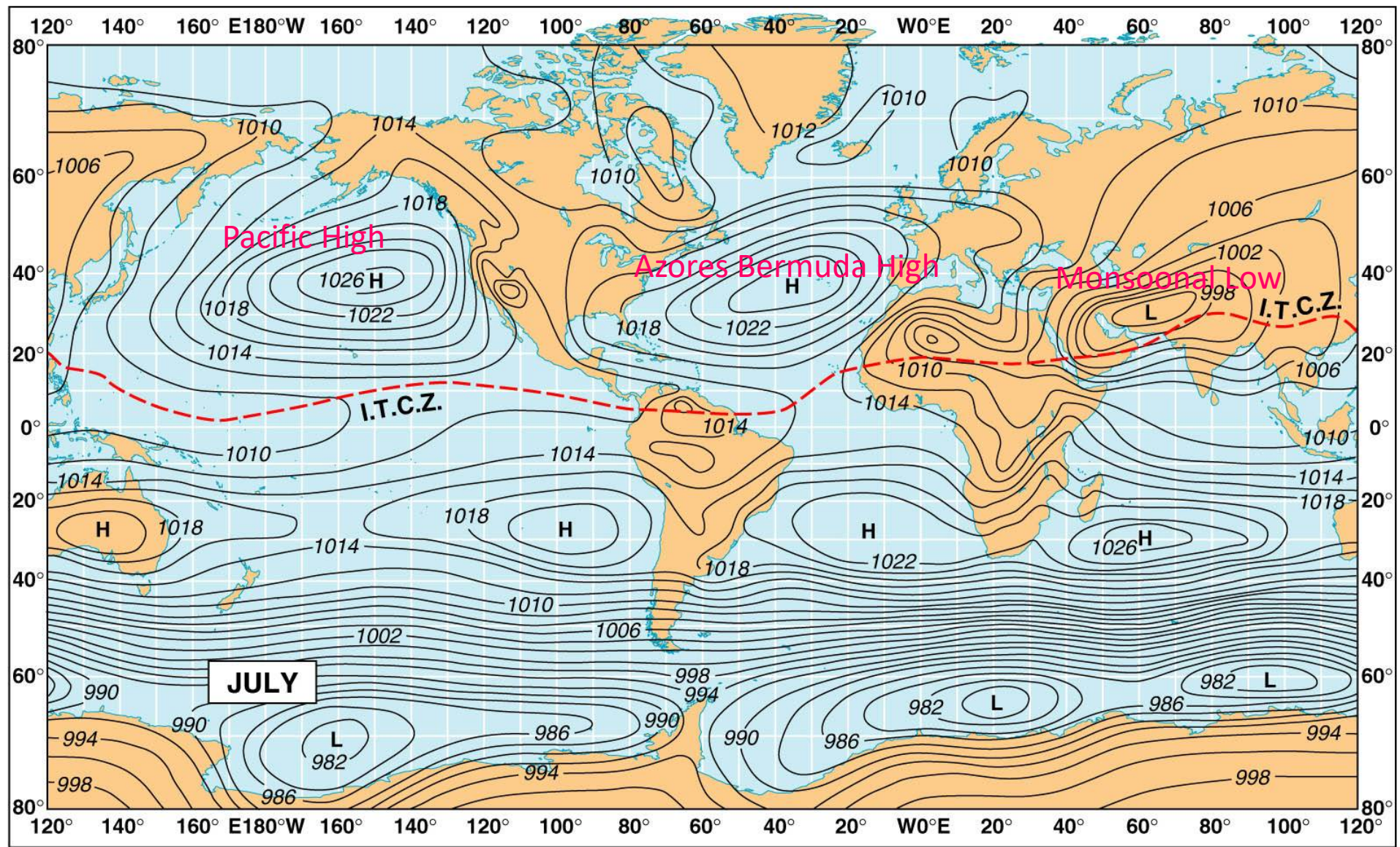
1) Meridional Temperature and Momentum Transport

- Stationary Eddies and Transient Eddies





(a)



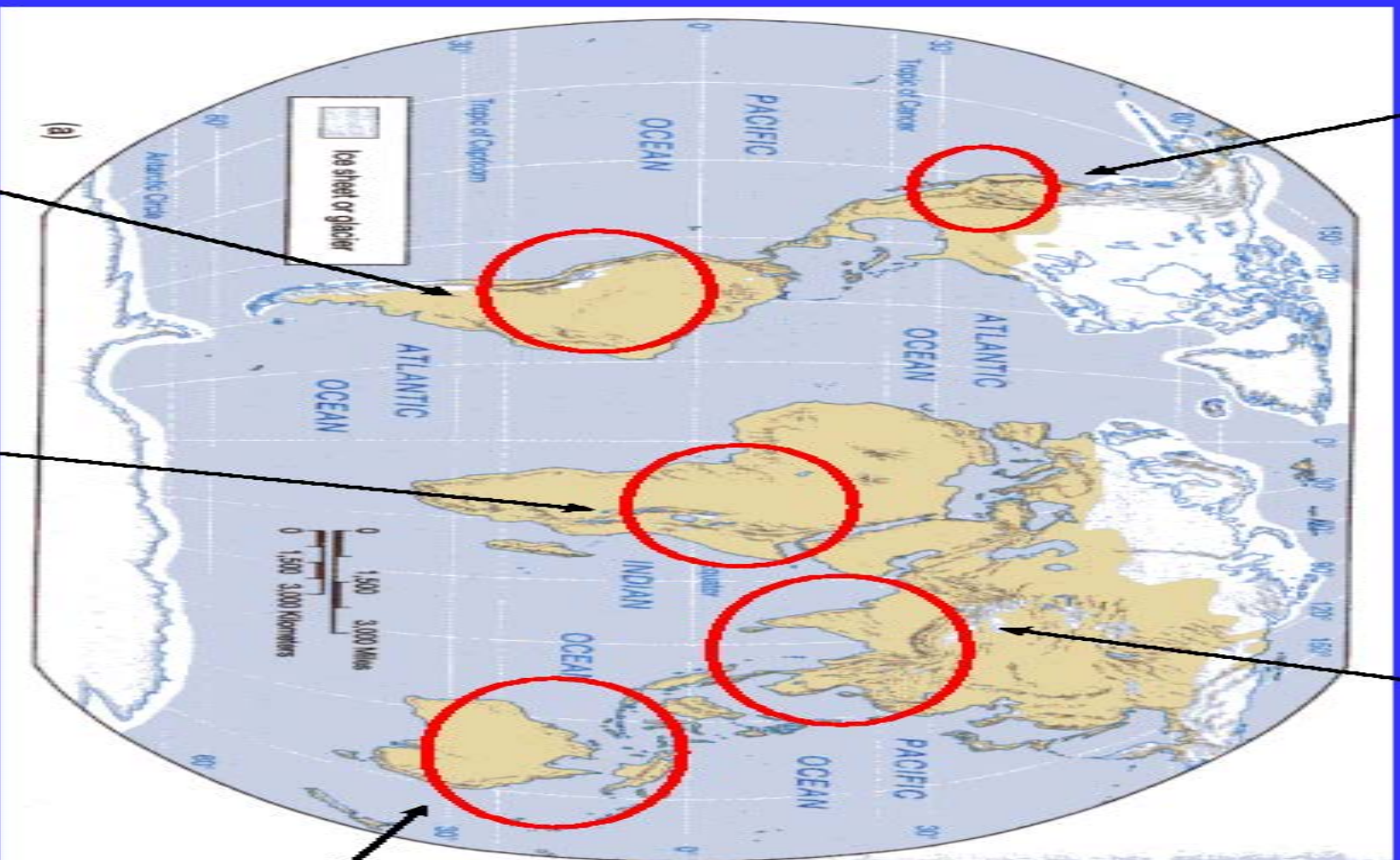
(b)

Global Deserts



North America Monsoon

Asian Monsoon



Australian Monsoon

Africa Monsoon

South America Monsoon

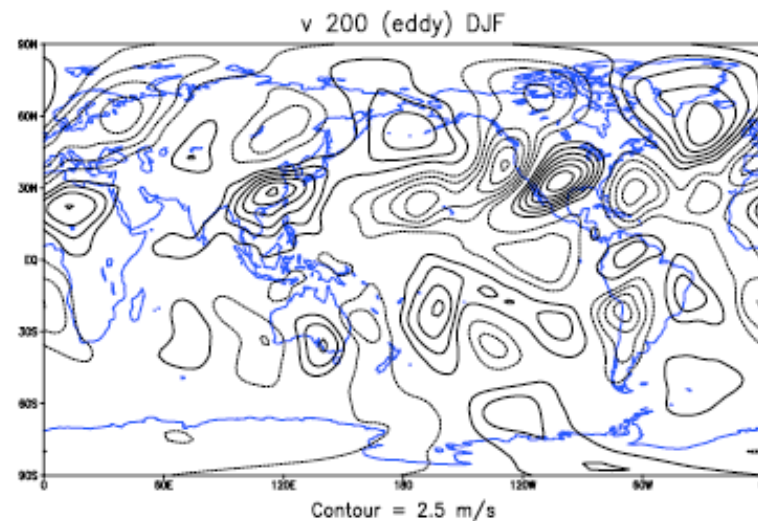
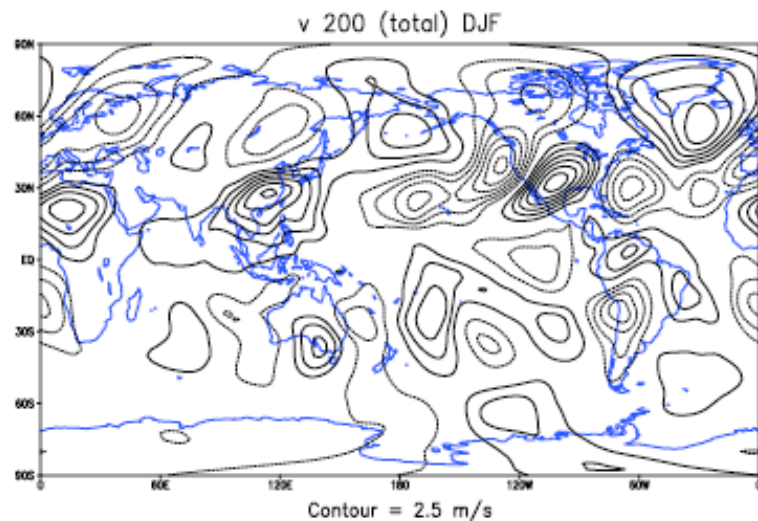
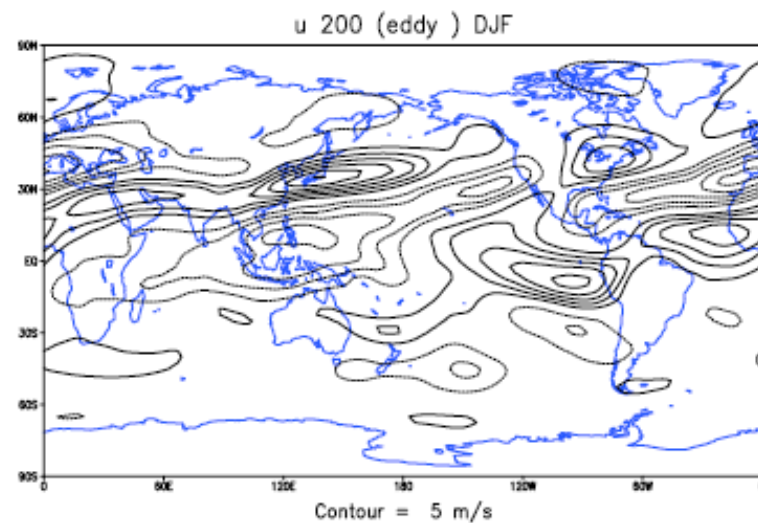
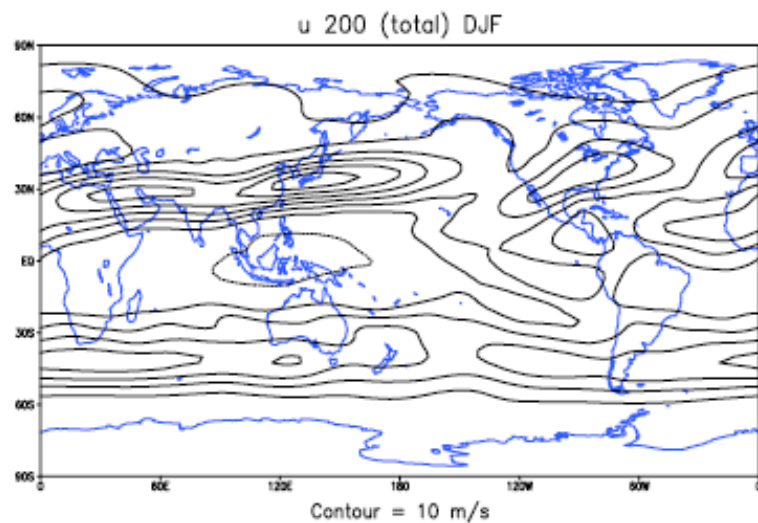


Figure 1: DJF 200 hPa u and v wind, total and eddy.

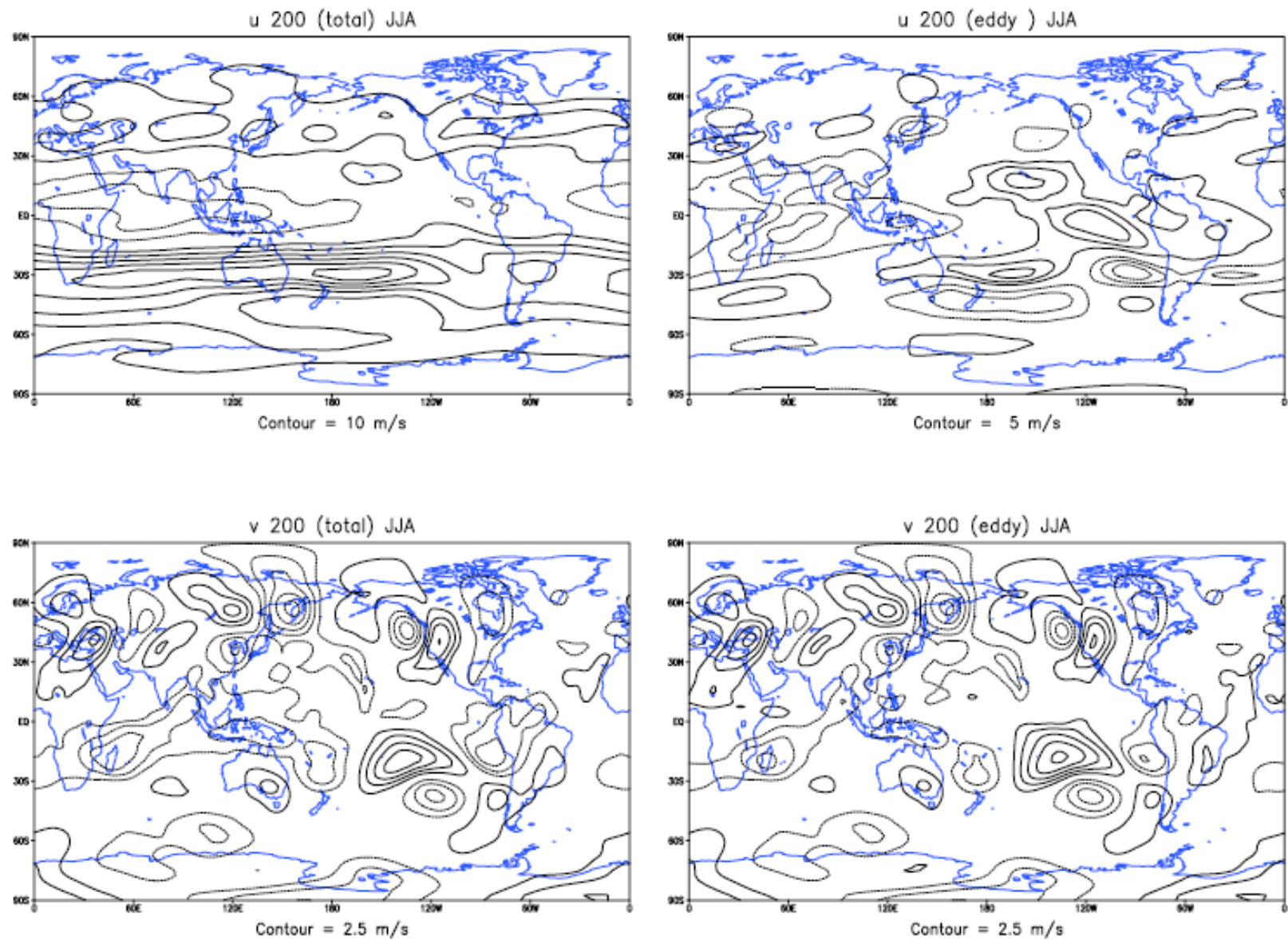
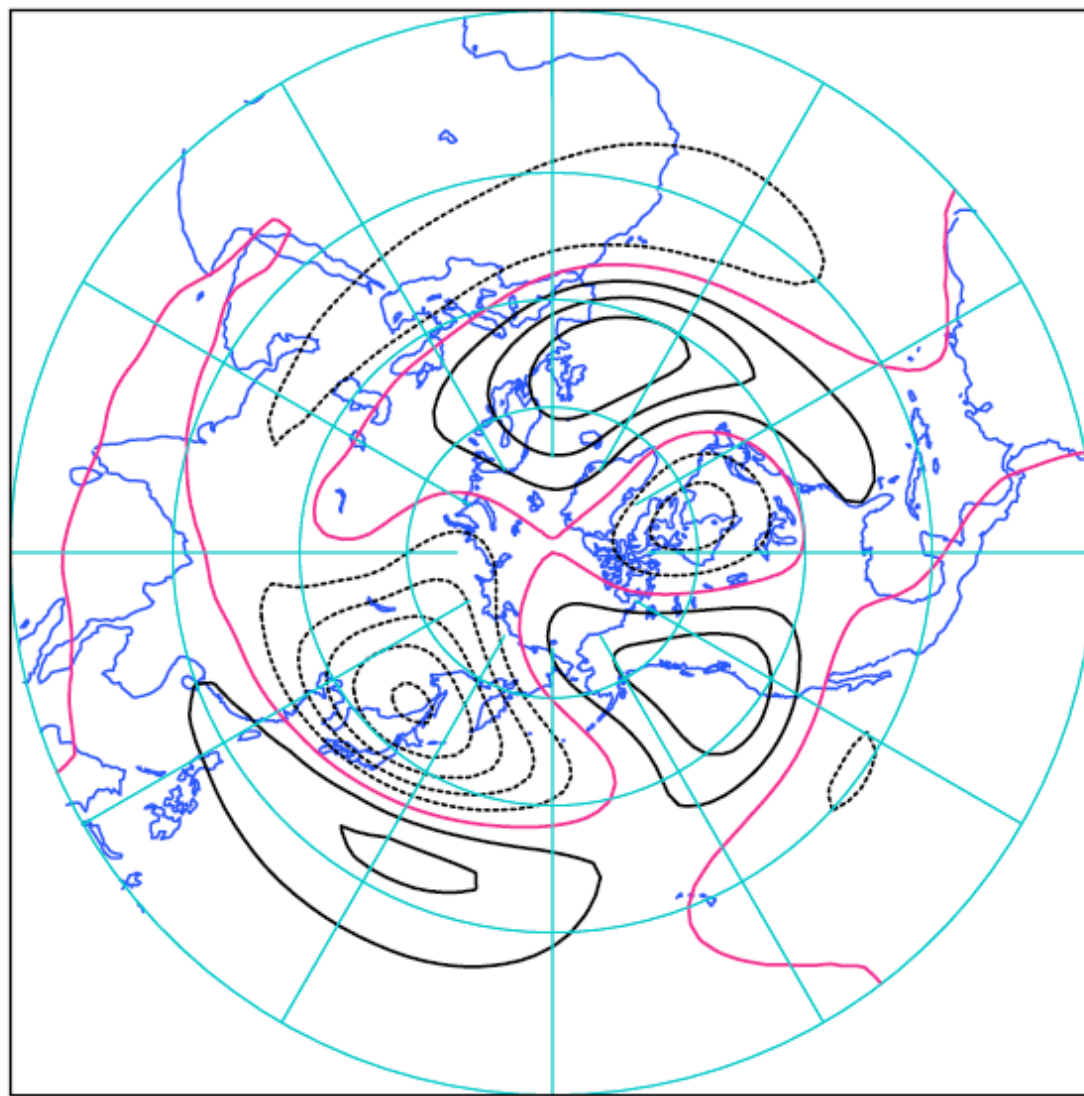


Figure 2: JJA 200 hPa u and v wind, total and eddy.

z 200 (eddy) DJF



13

Contour = 60 m

Figure 3: DJF 200 hPa Z eddy.

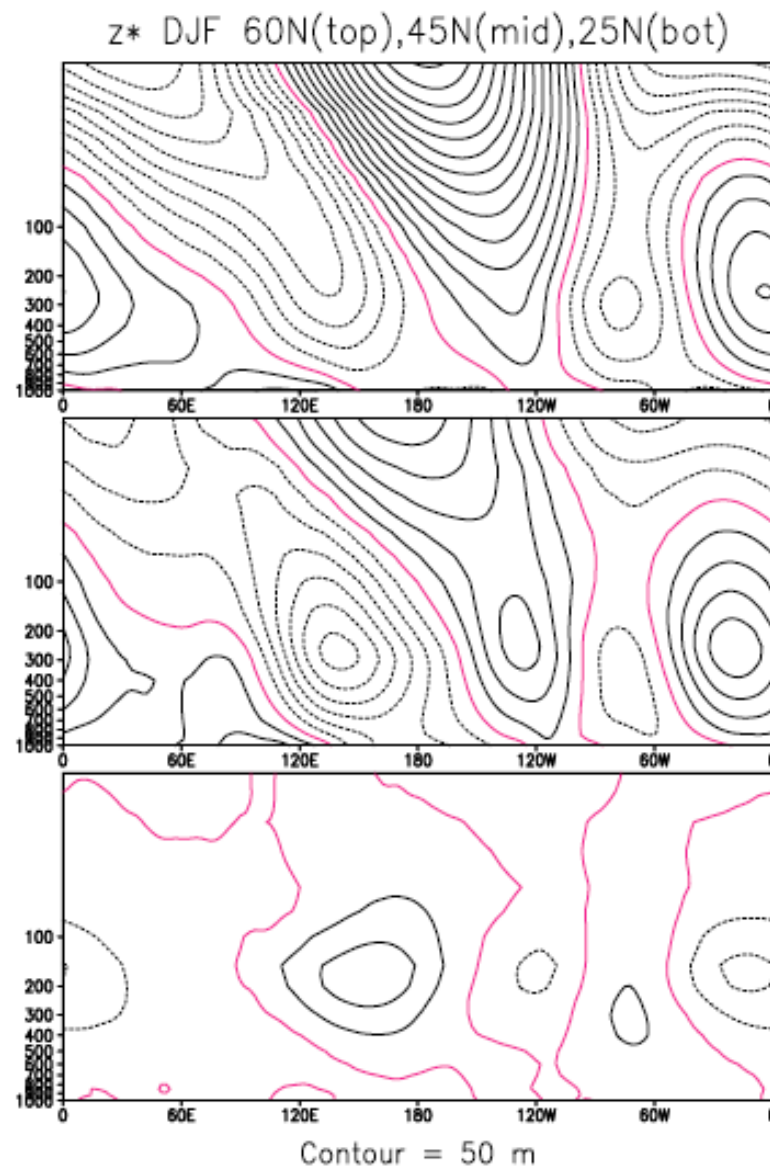
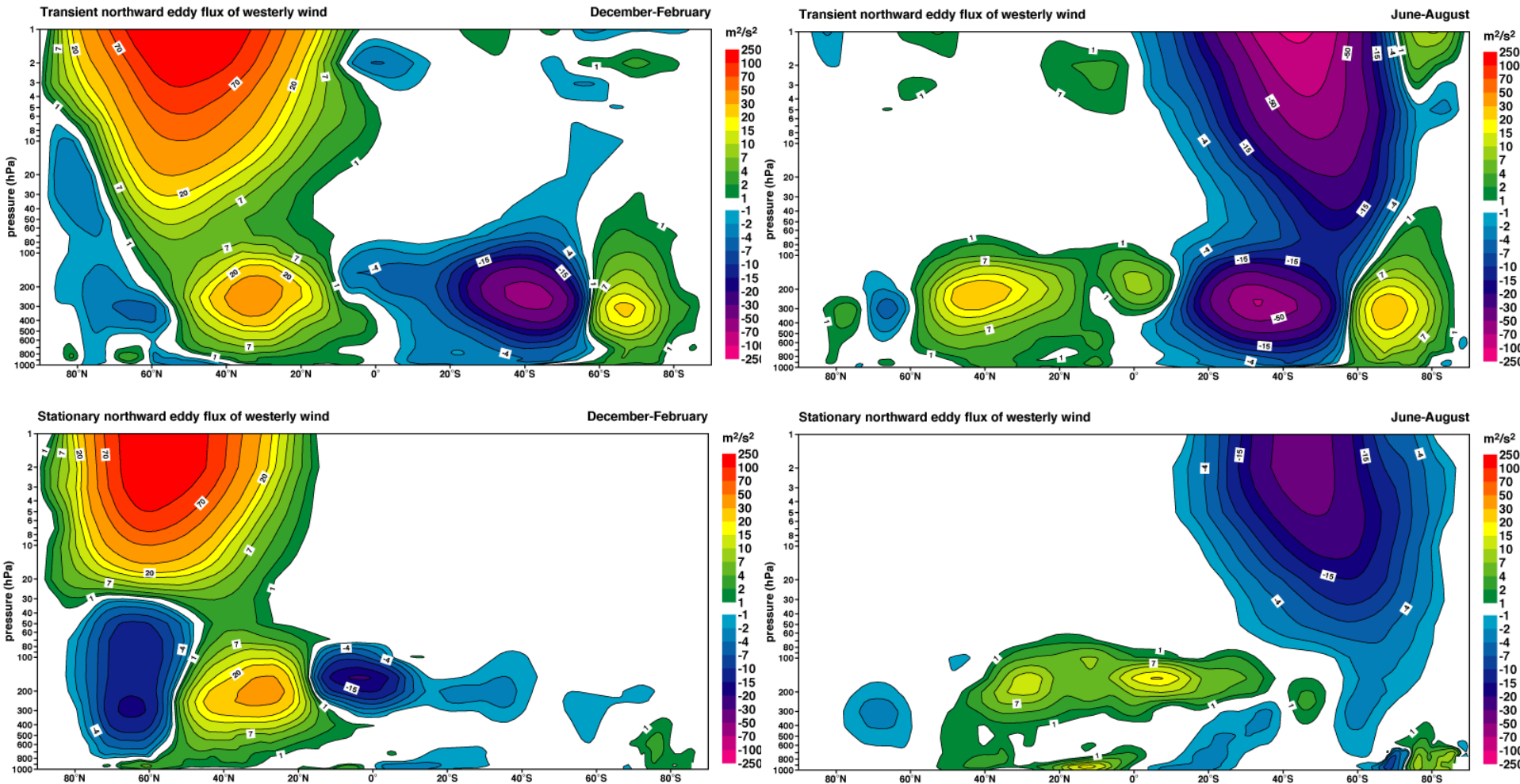
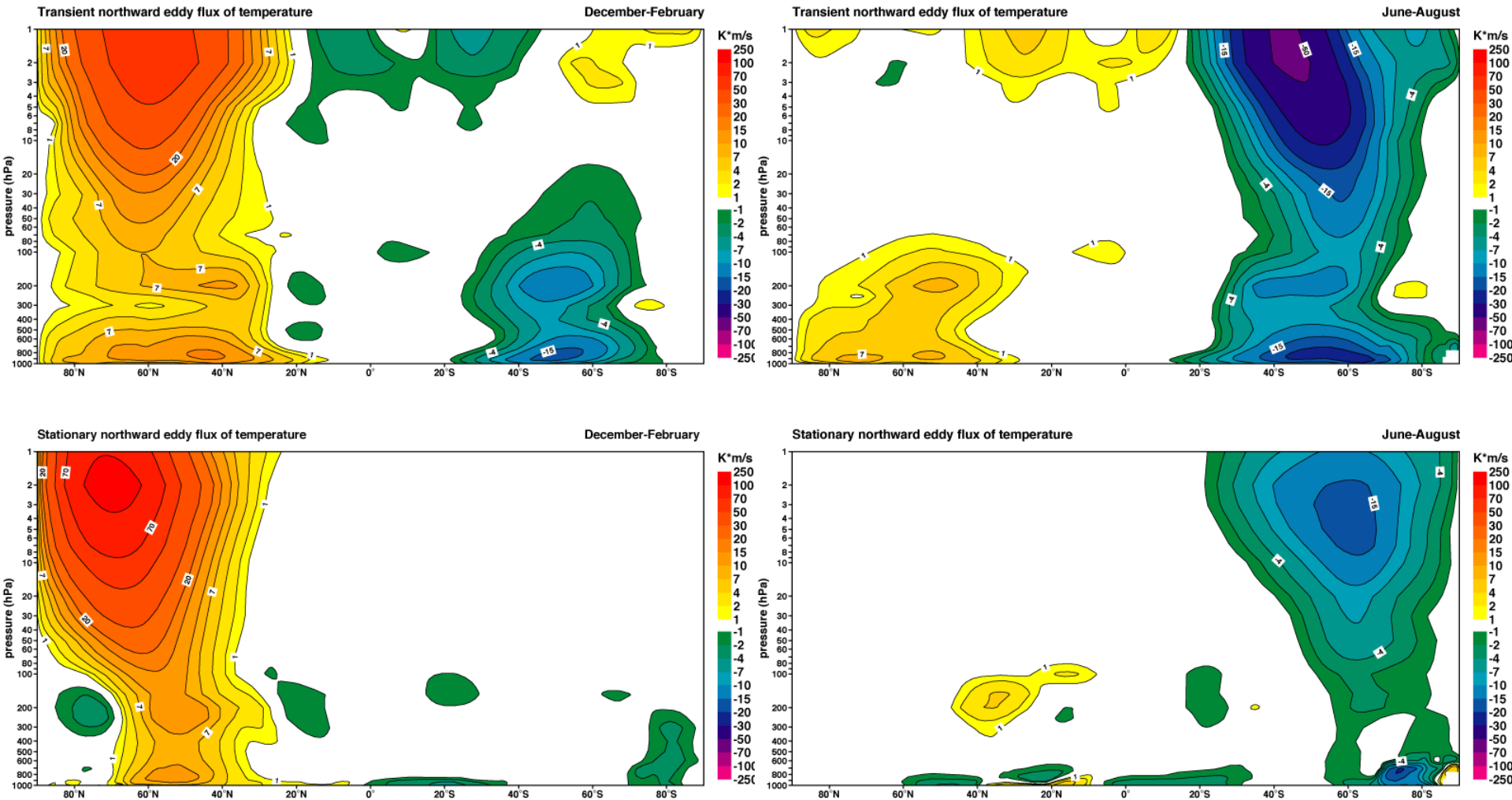


Figure 4: Longitude/Pressure sections of DJF Z^* at 60N (top), 45N(mid), and 25N(lower) .

Transient and Stationary Eddy Flux of Westerly Momentum



Transient and Stationary Eddy Flux of Temperature



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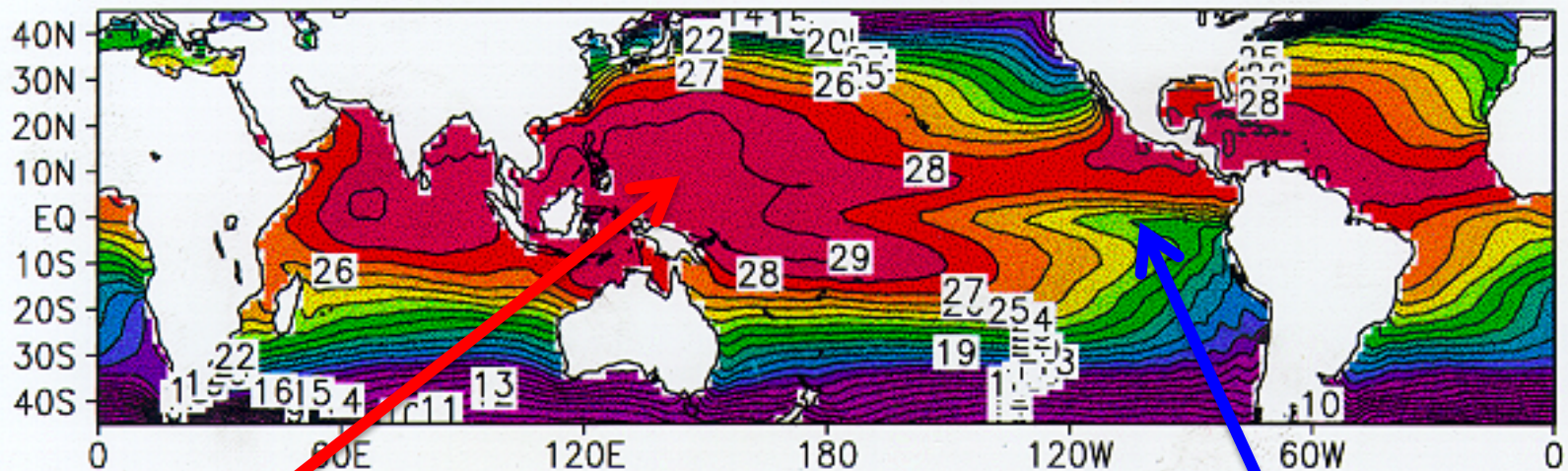
2) Large-Scale Tropics

- ENSO

3) Climate Change

September-October-November Sea Surface Temperature Climatology

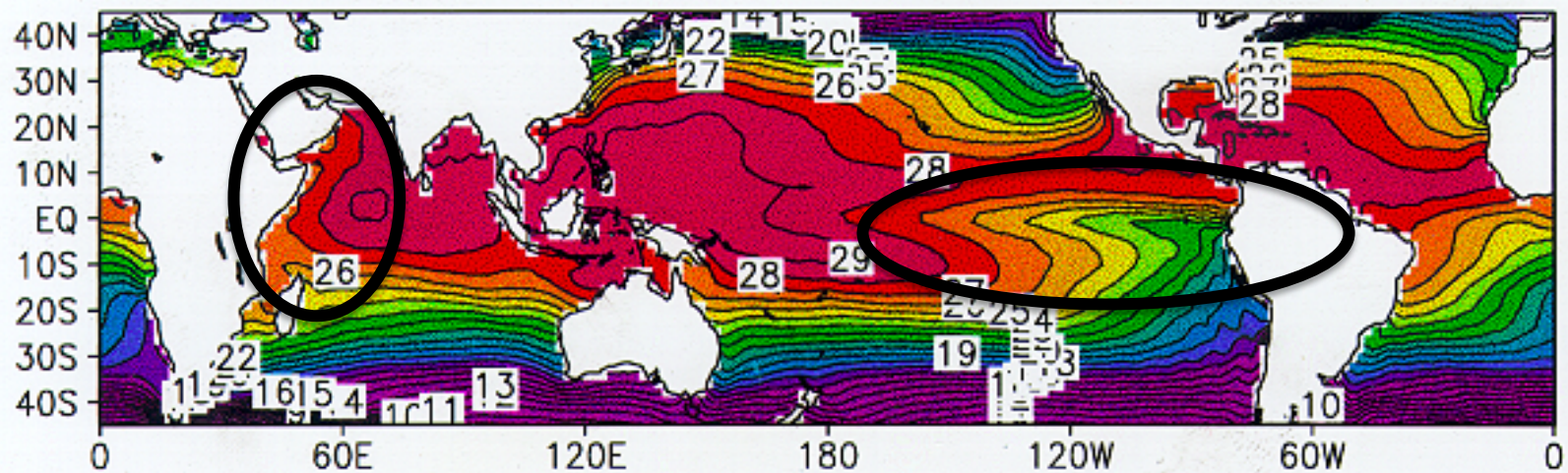
Sea Surface Temp SON Climo



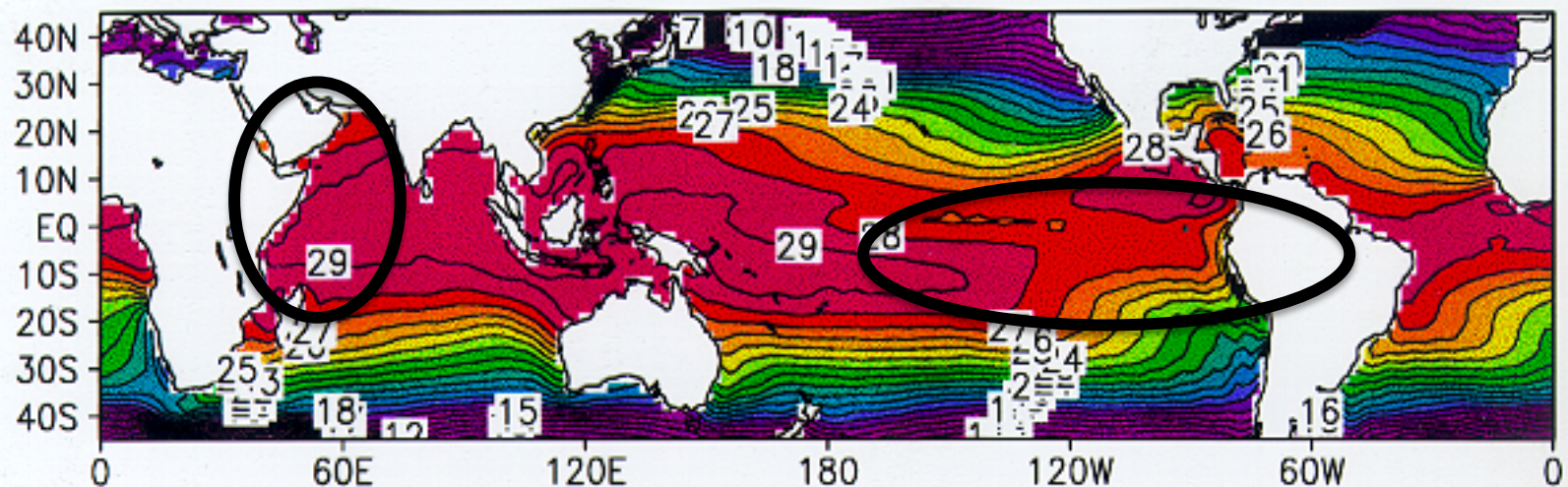
Warm Pool

Cold Tongue

Sea Surface Temp SON Climo



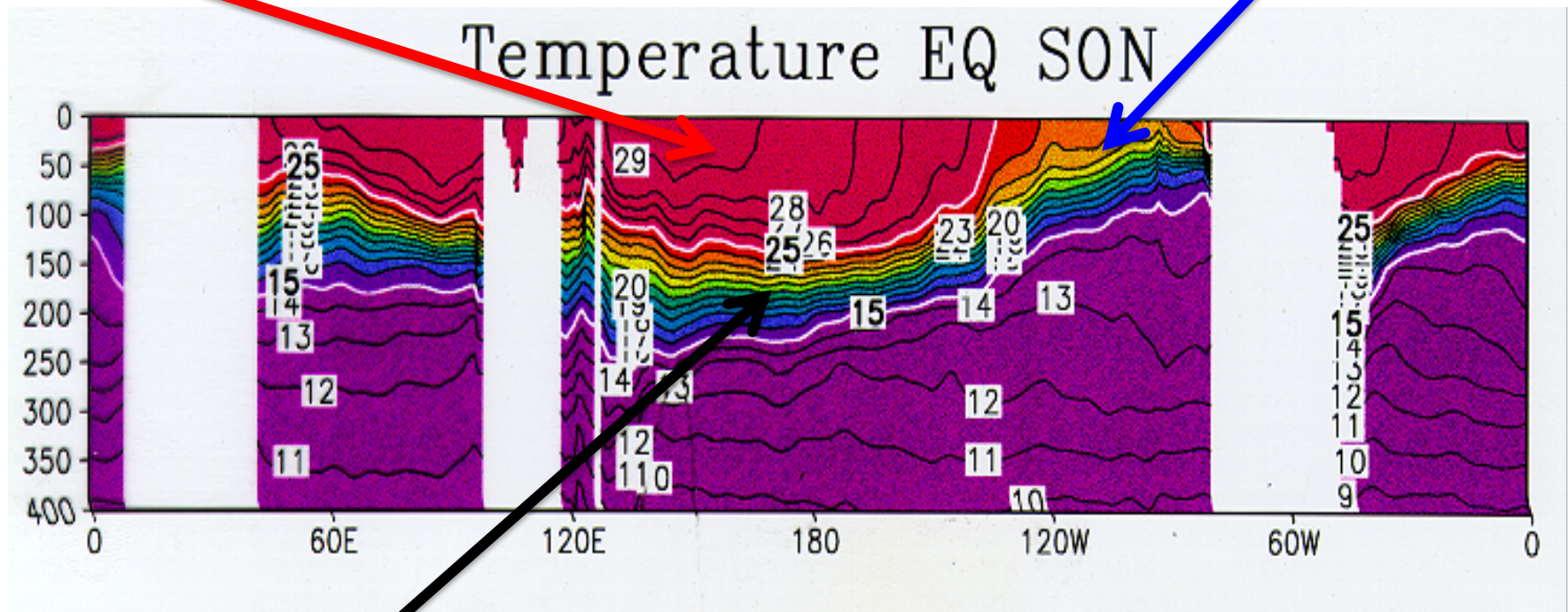
Sea Surface Temp MAM Climo



September-October-November Equatorial Temperature Climatology

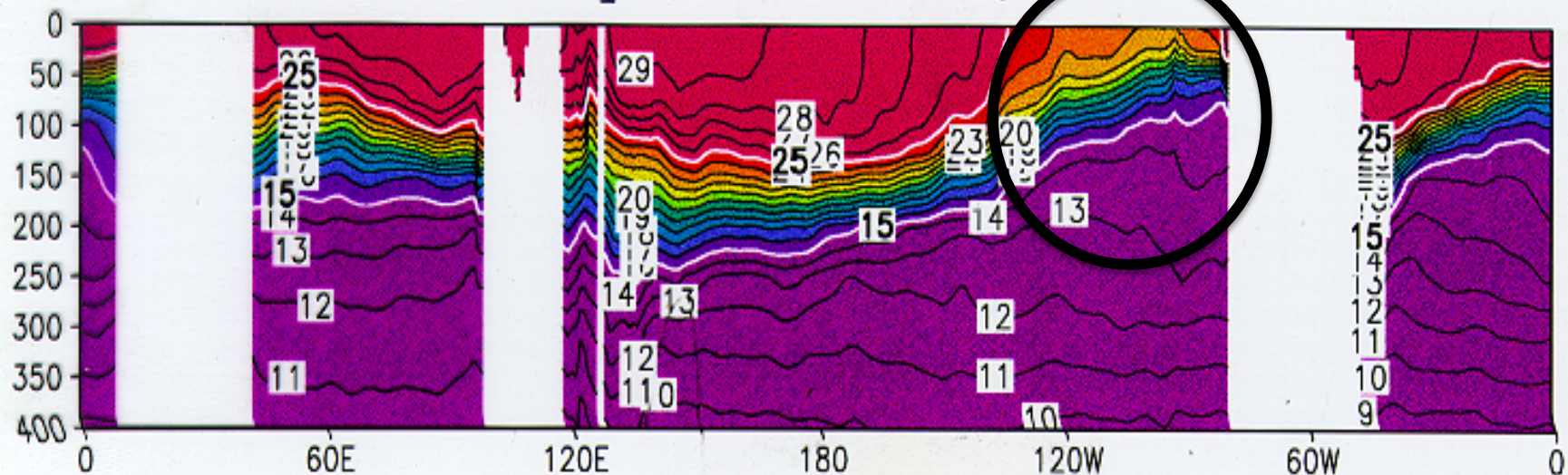
Warm Pool

Cold Tongue

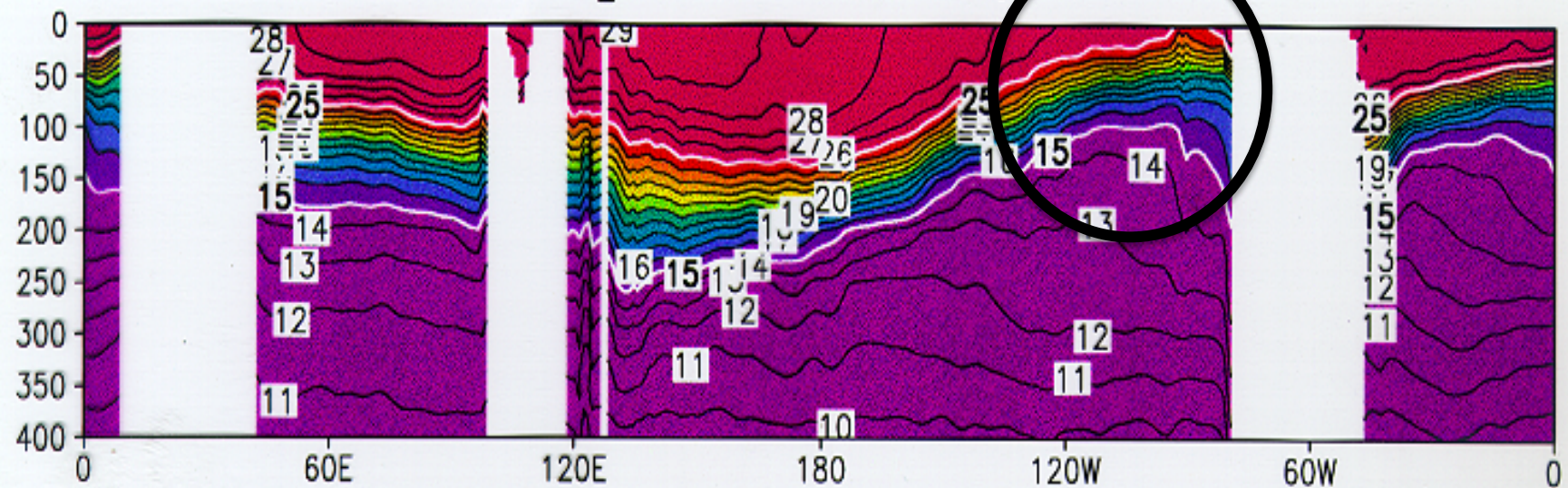


Thermocline

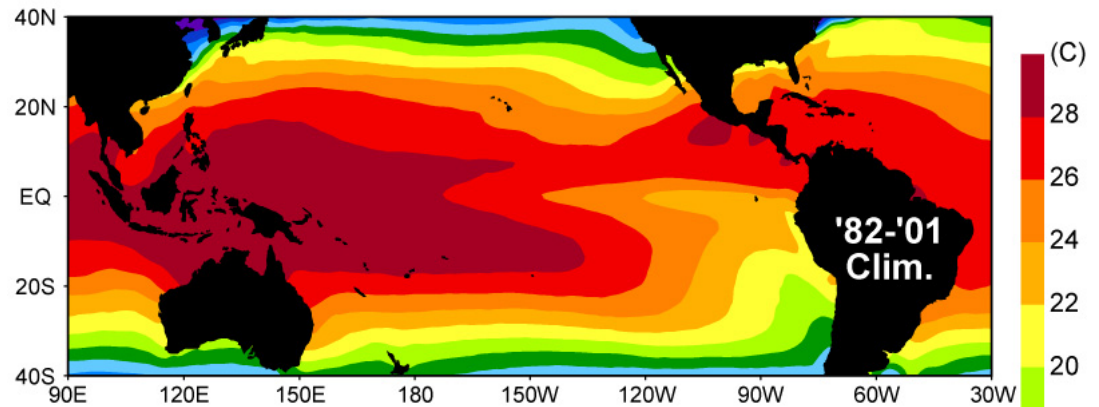
Temperature EQ SON



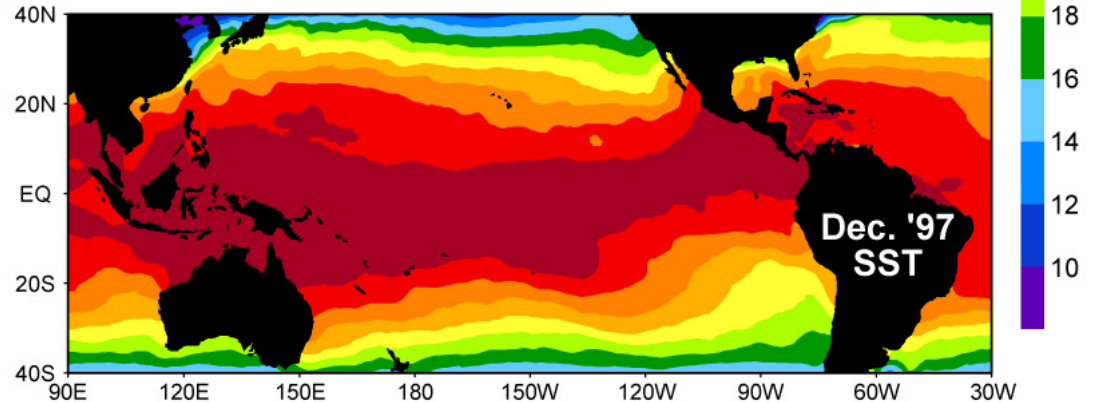
Temperature EQ MAM



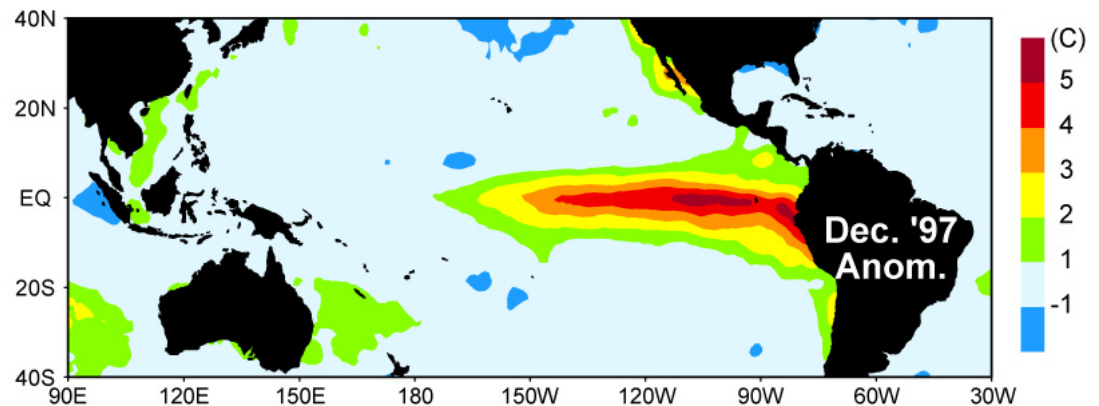
December 1982-2001 SST Climatology



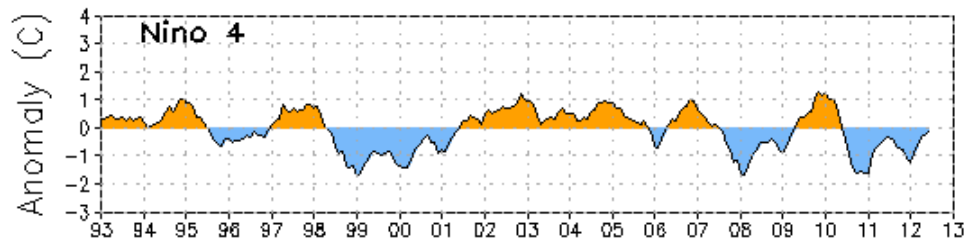
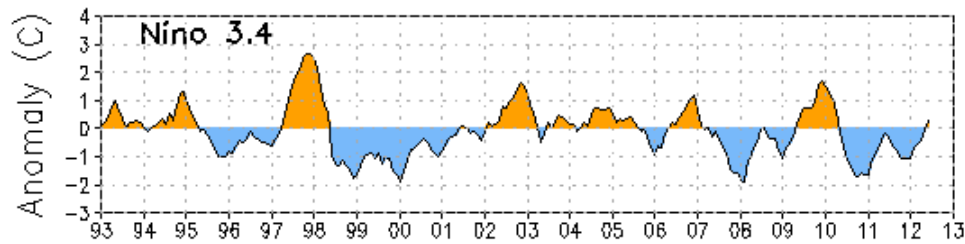
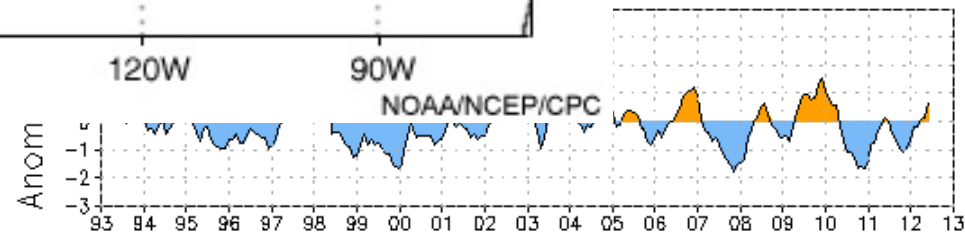
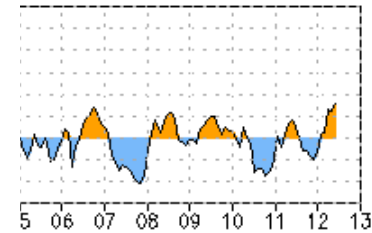
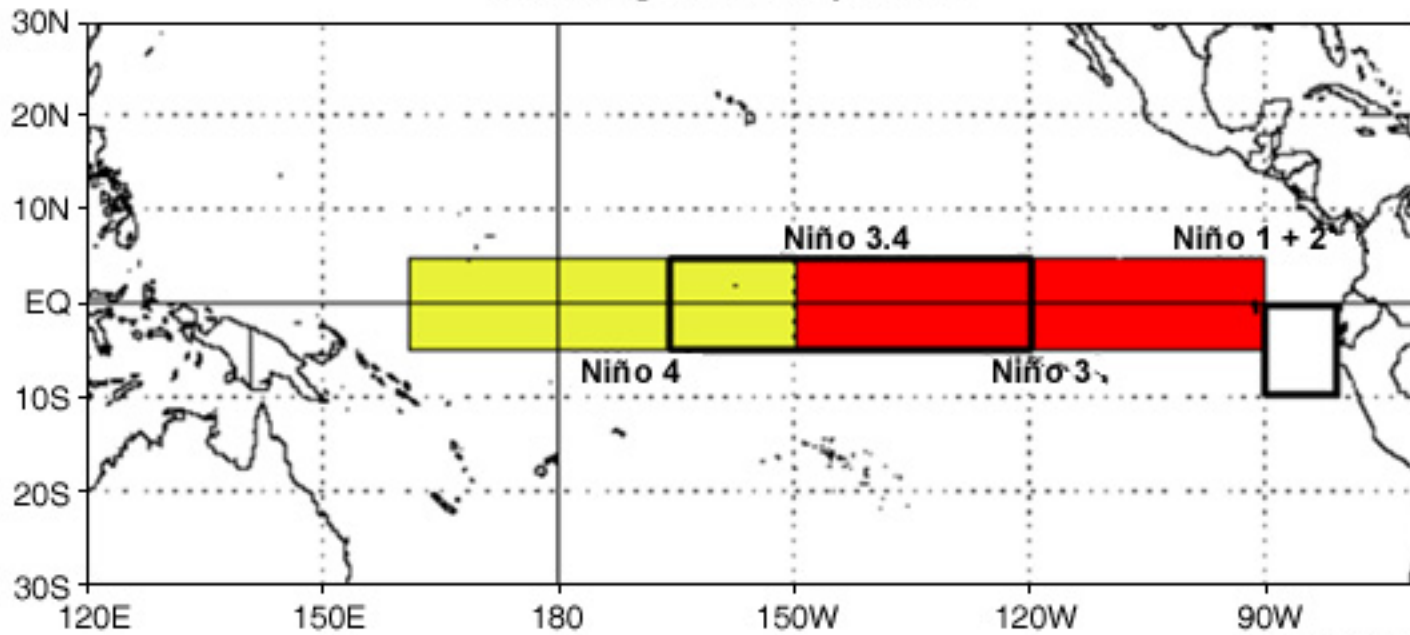
December 1997 Total SST



December 1997 SST Anomaly

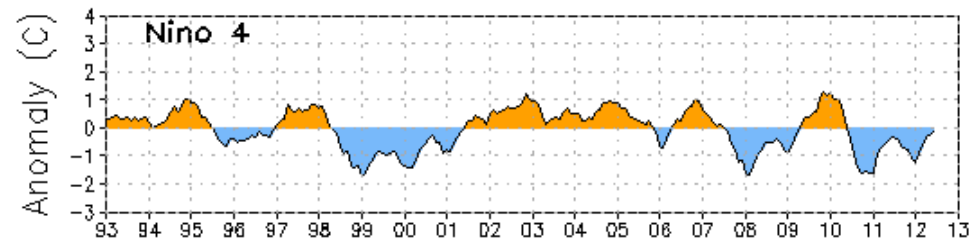
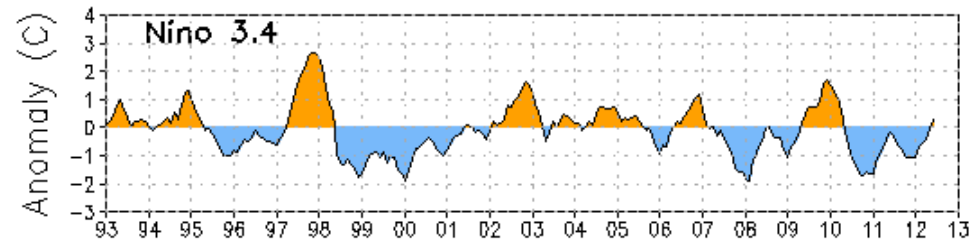
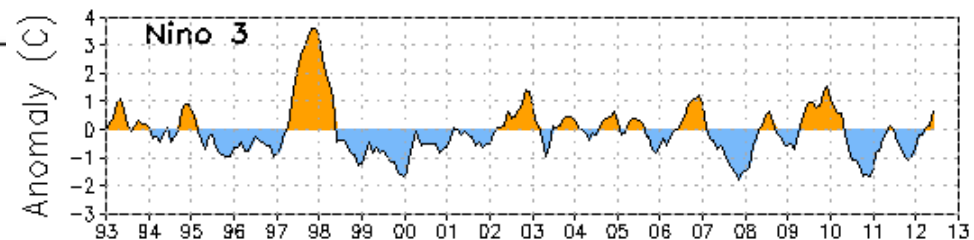
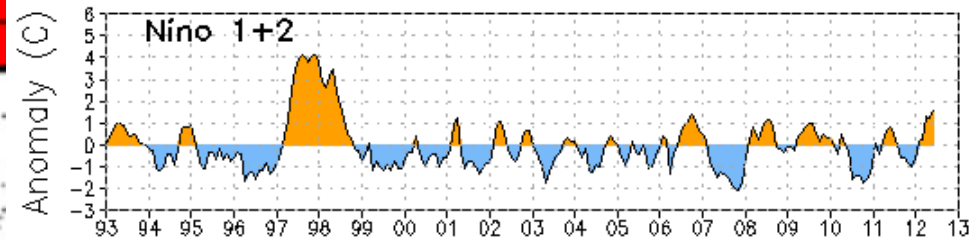
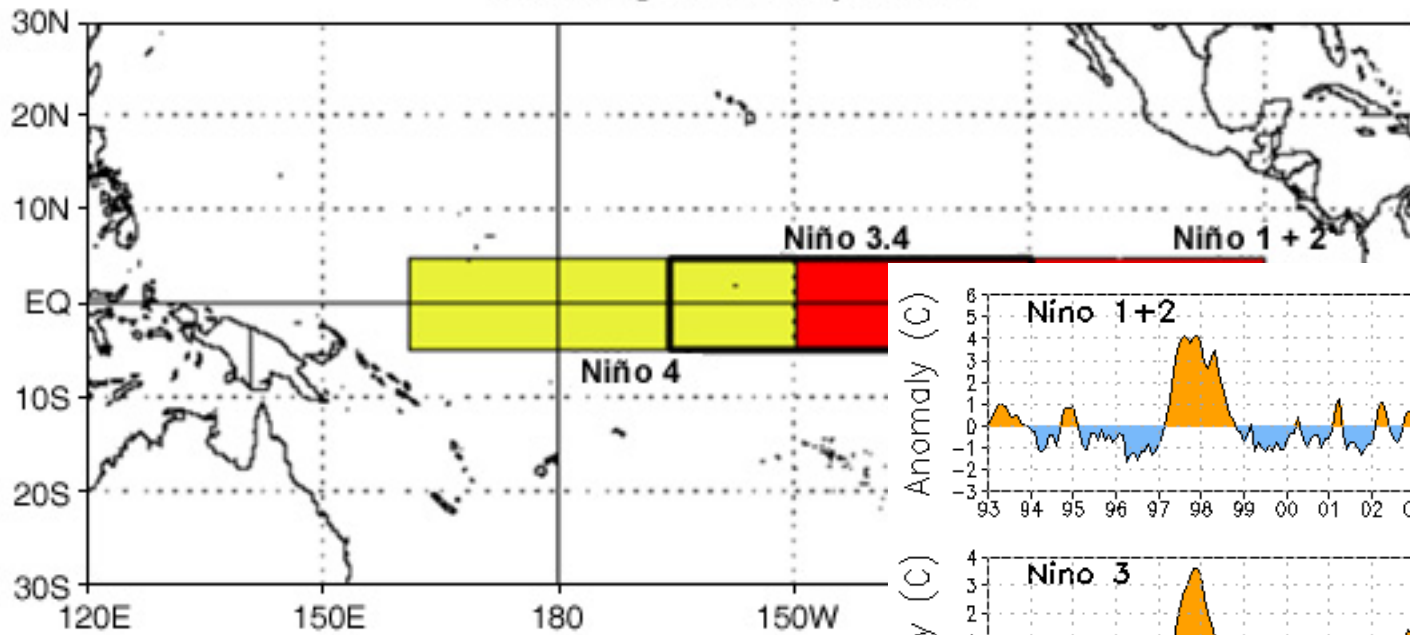


Monitoring Ocean Temperature



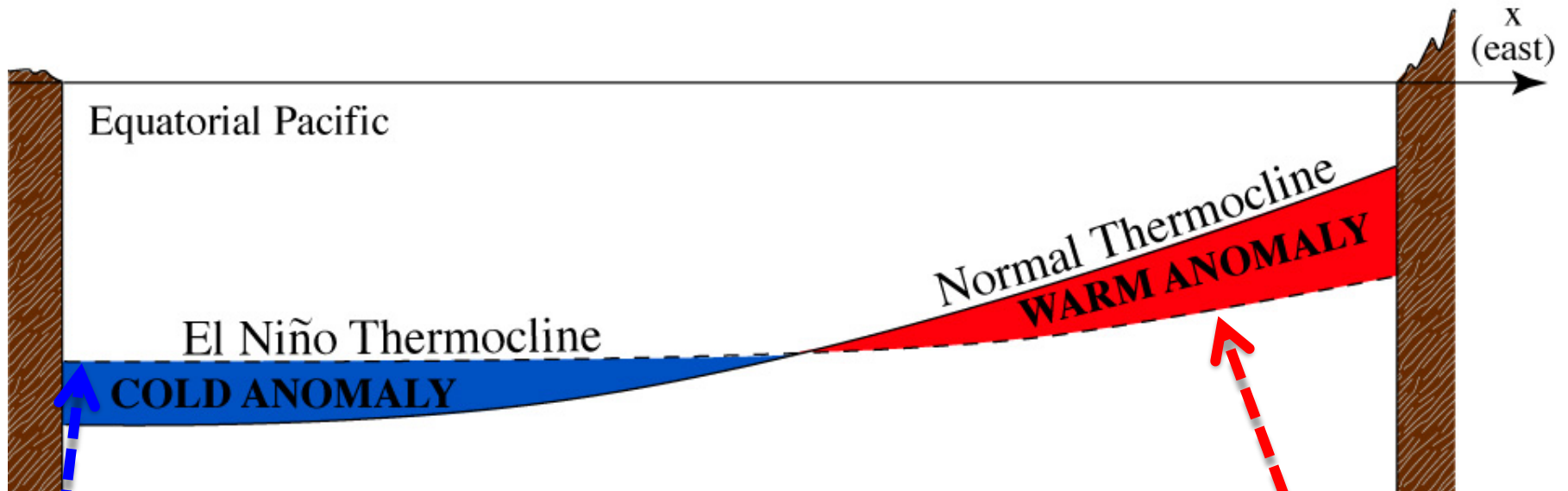
Data updated through June 2012

Monitoring Ocean Temperature



Data updated through June 2012

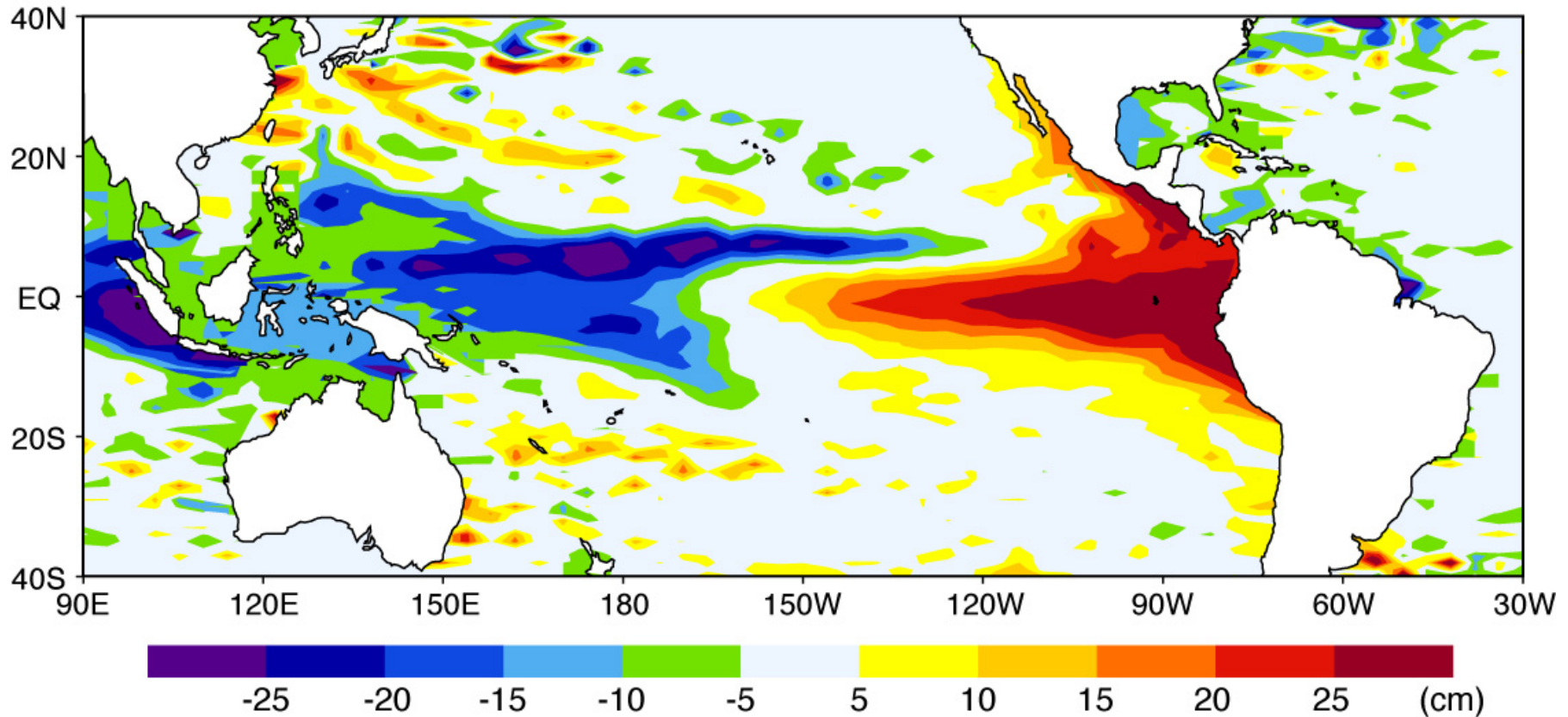
El Nino vs. Normal Thermocline Depth

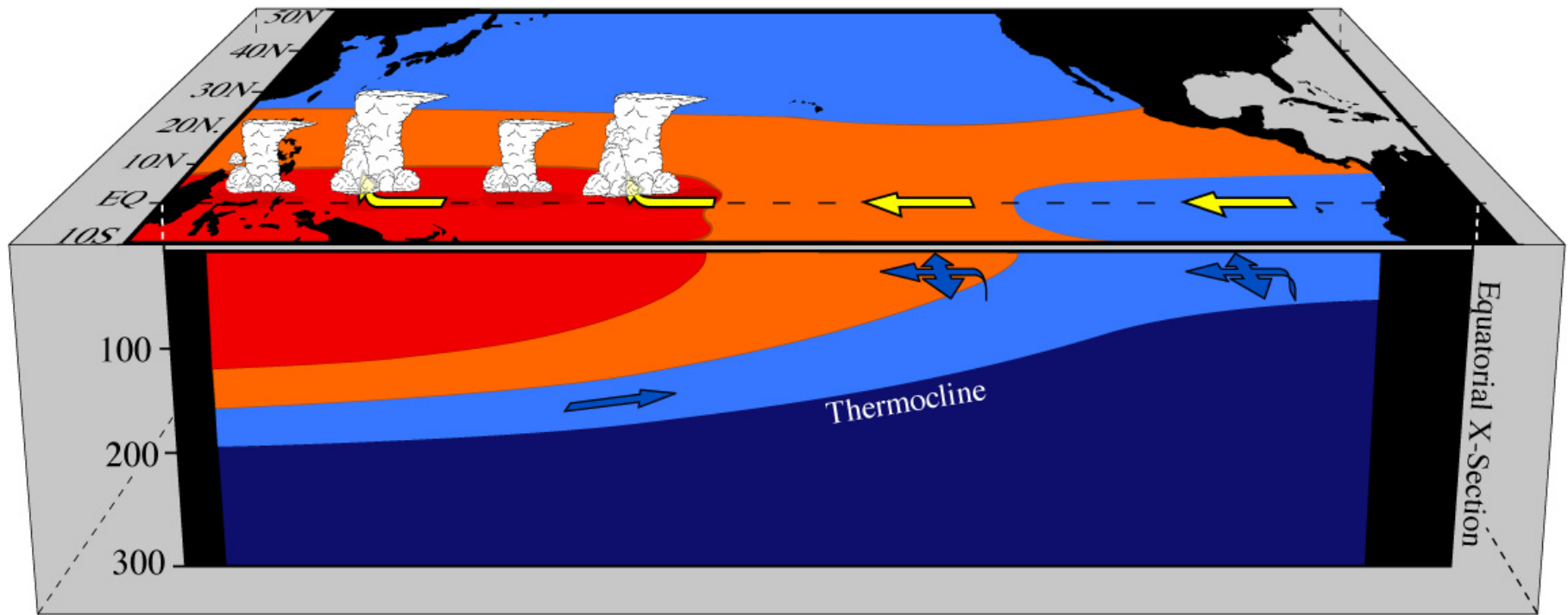


Thermocline is Shallower
than Normal
Negative Depth Anomaly

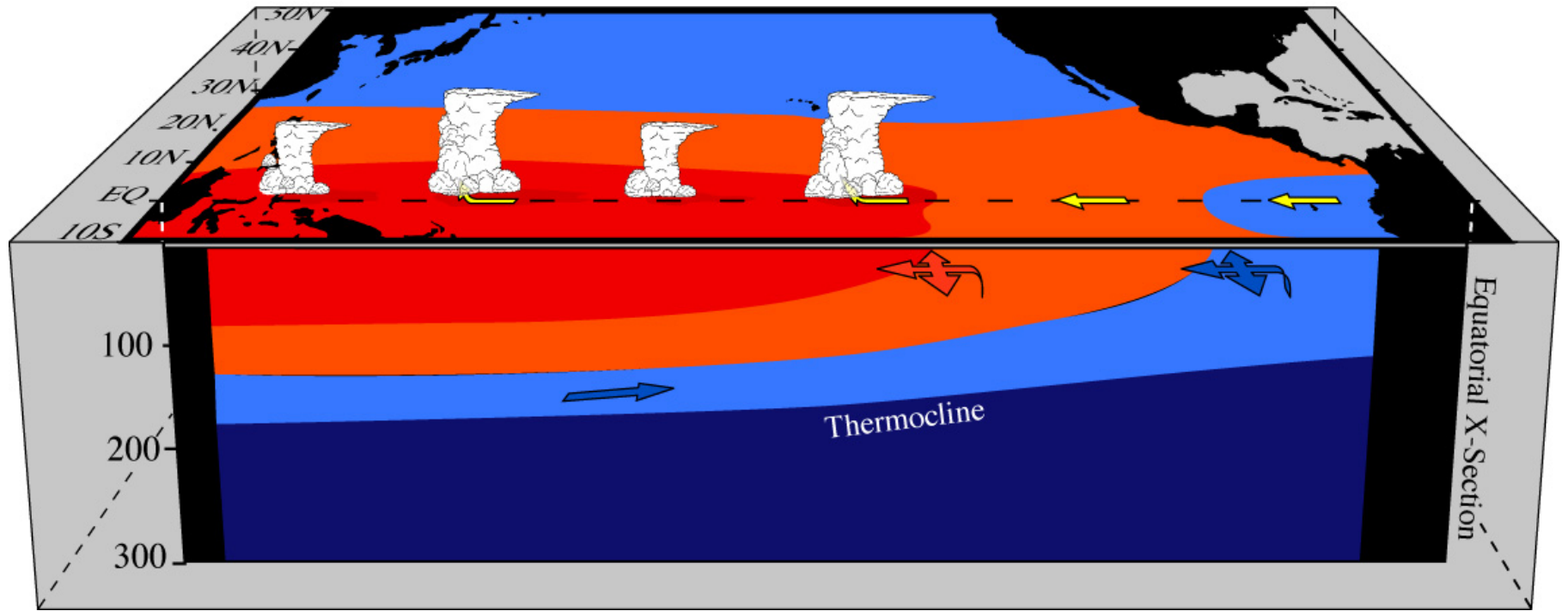
Thermocline is Deeper than
Normal
Positive Depth Anomaly

December 1997 (El Nino) Thermocline Depth Anomalies

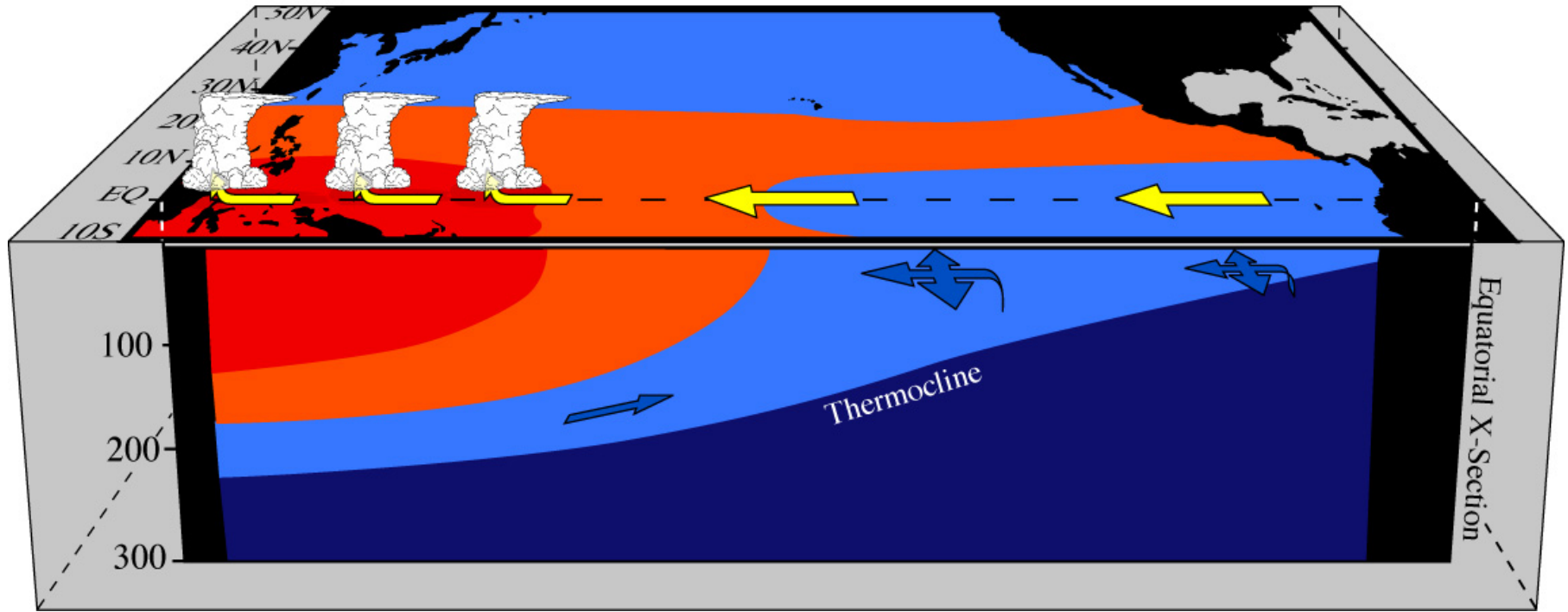




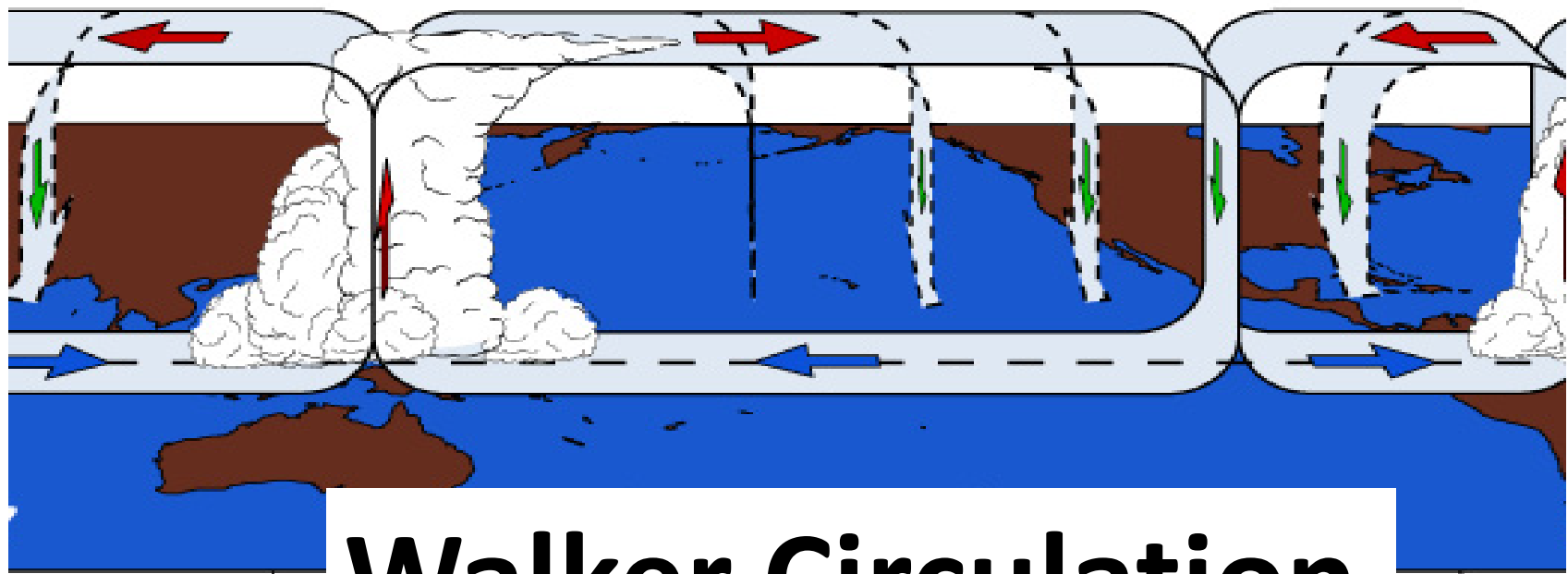
Normal Conditions in the Tropical Pacific



Warm (El Nino) Conditions in the Tropical Pacific



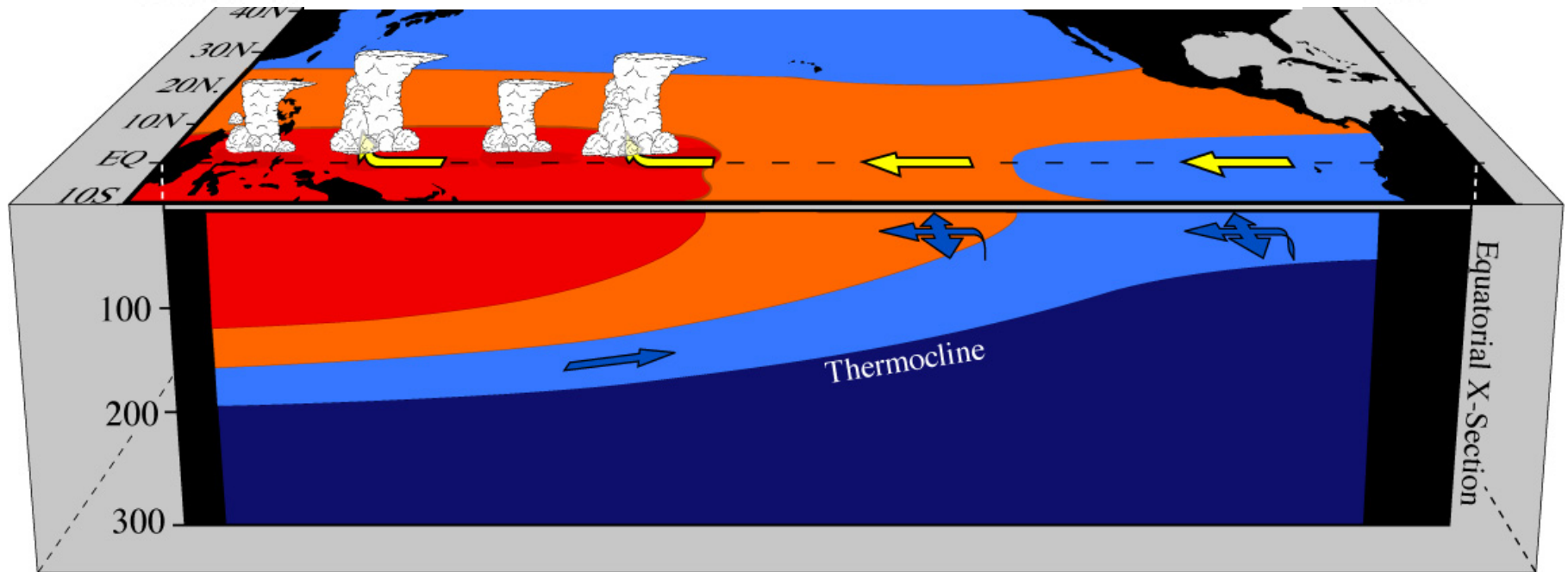
Cold (La Nina) Conditions in the Tropical Pacific

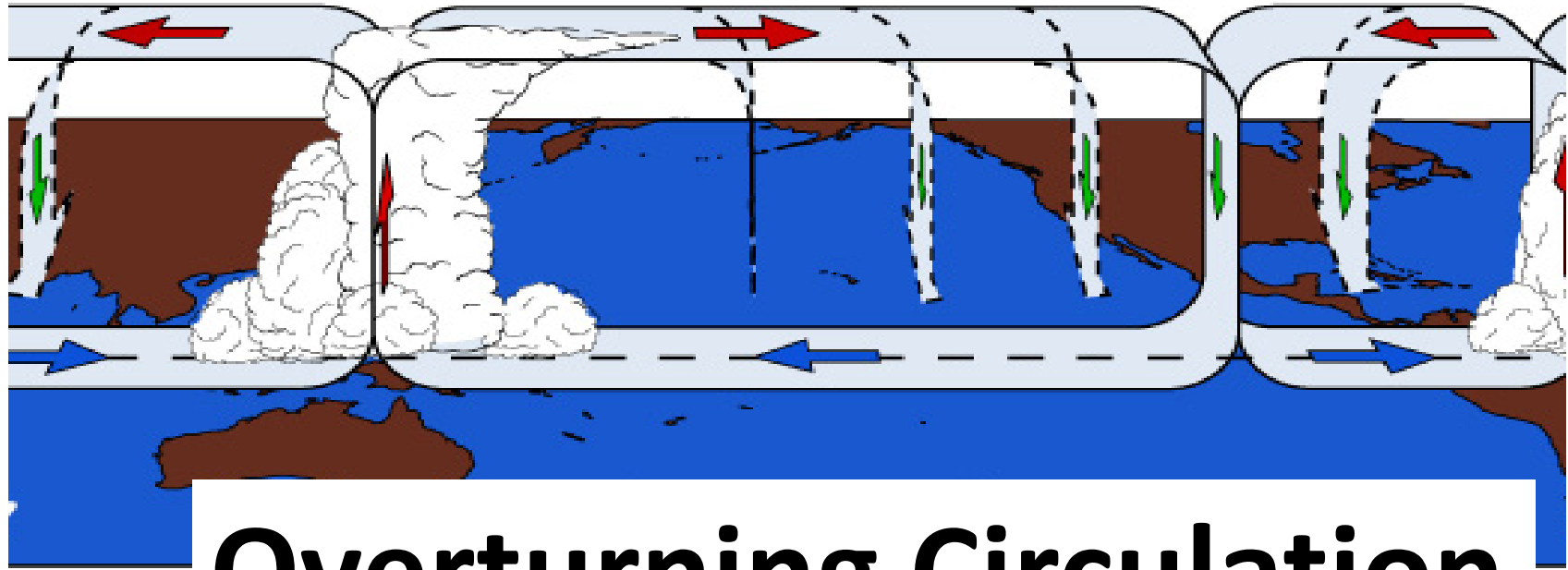


Walker Circulation

135°E

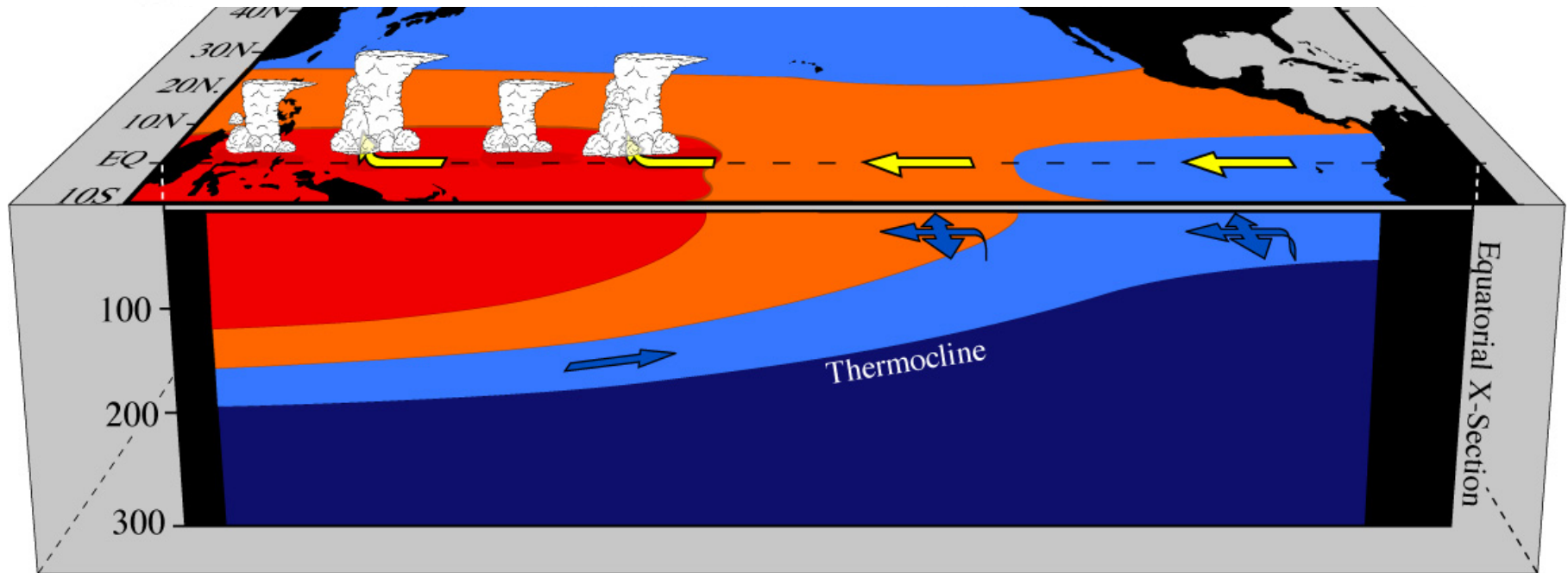
90°





1

Overturning Circulation



Warm SST
anomaly

BJERKNES
FEEDBACK

Weakening Walker
circulation;
Weakening easterlies

Flow of warm
water in layer above thermo-
cline toward **east, deepening**
of thermocline in east

Equatorial upwelling
brings up water that is
less cold than normal

```
graph TD; A([Warm SST anomaly]) --> B([Weakening Walker circulation; Weakening easterlies]); B --> C([Flow of warm water in layer above thermocline toward east, deepening of thermocline in east]); C --> D([Equatorial upwelling brings up water that is less cold than normal]); D --> A;
```

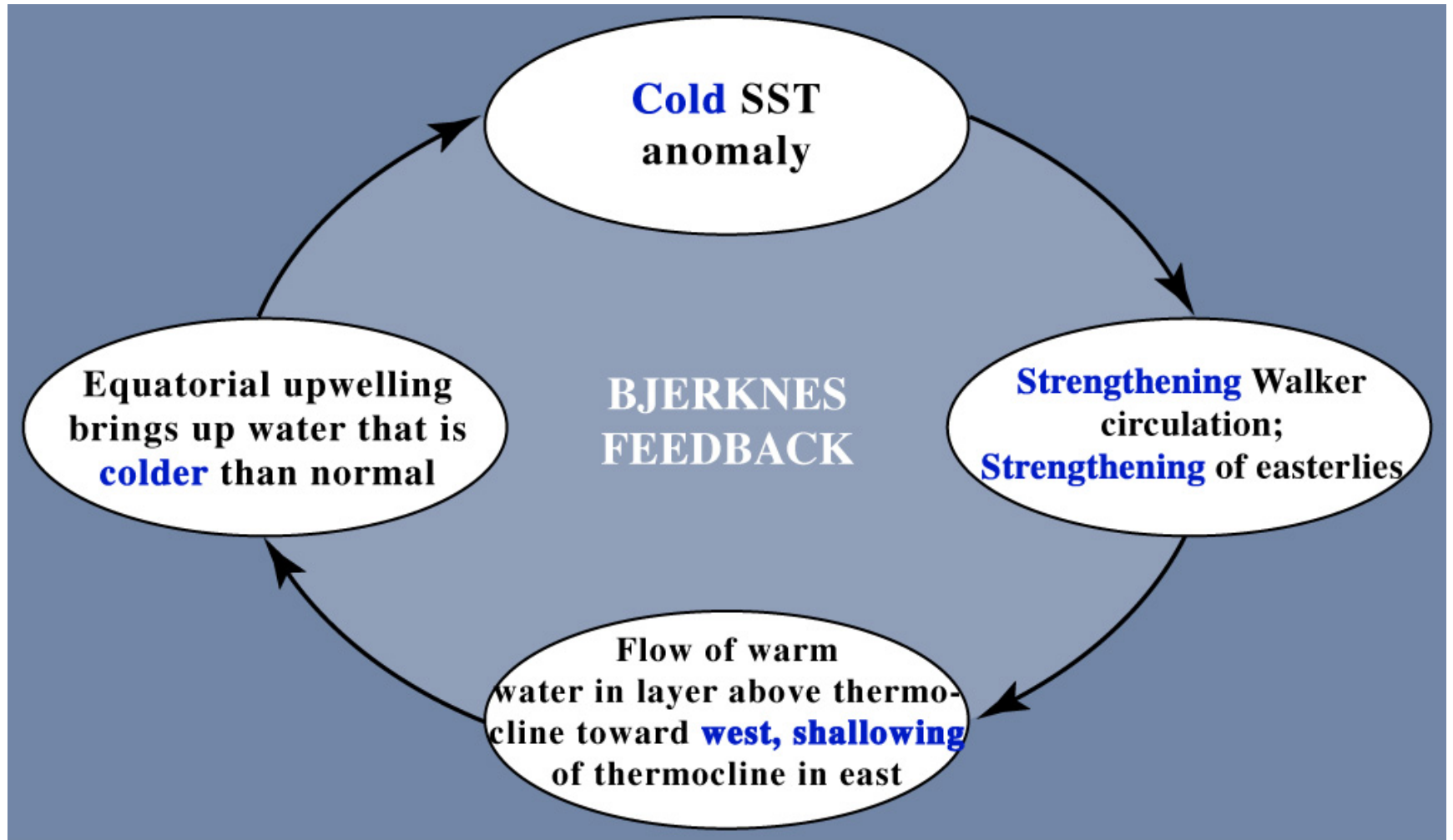
**Cold SST
anomaly**

Equatorial upwelling
brings up water that is
colder than normal

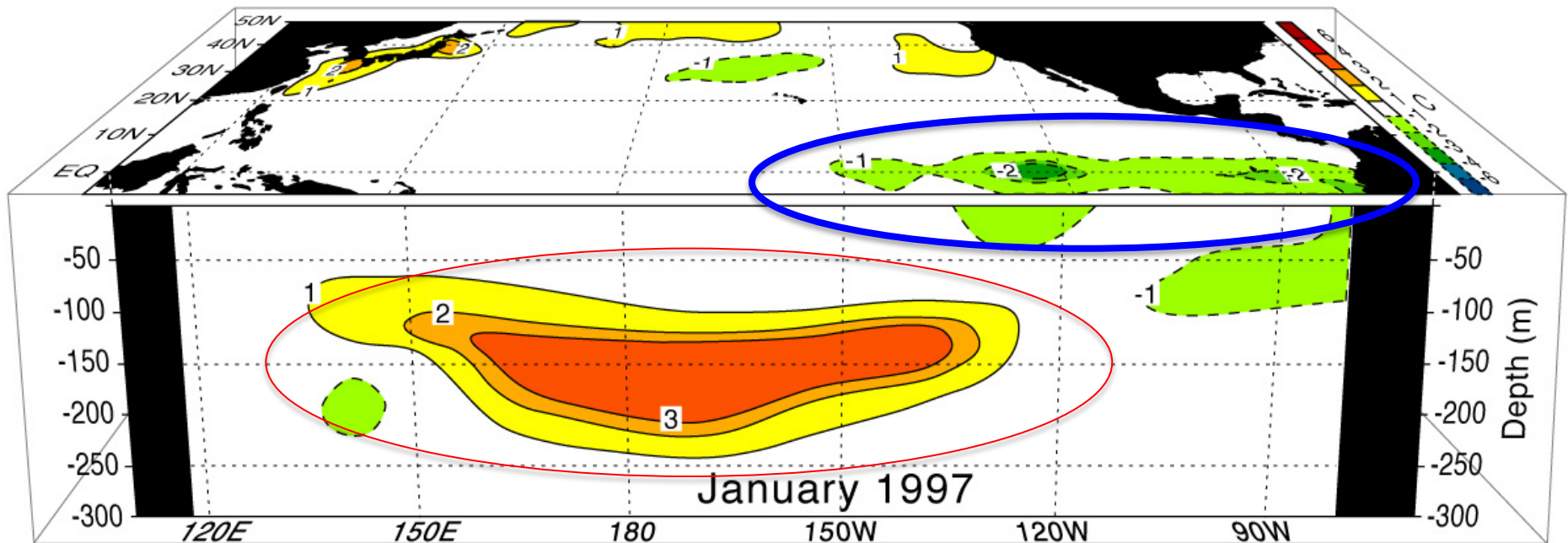
**BJERKNES
FEEDBACK**

Strengthening Walker
circulation;
Strengthening of easterlies

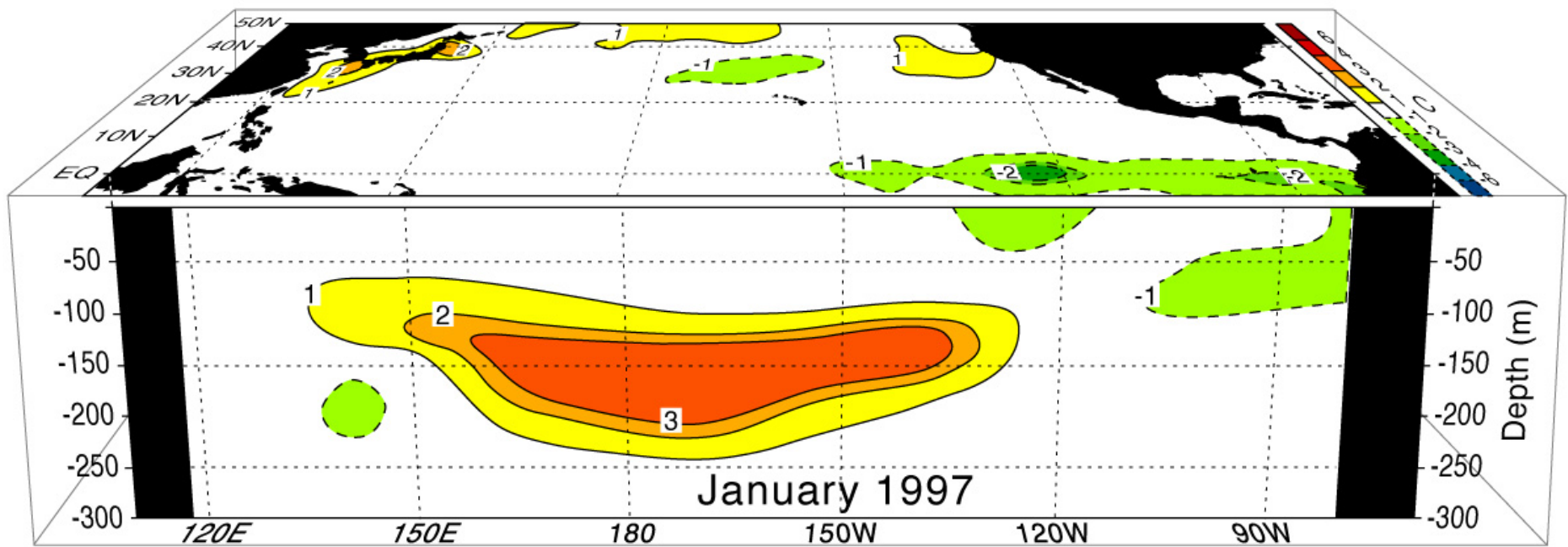
Flow of warm
water in layer above thermo-
cline toward **west, shallowing**
of thermocline in east

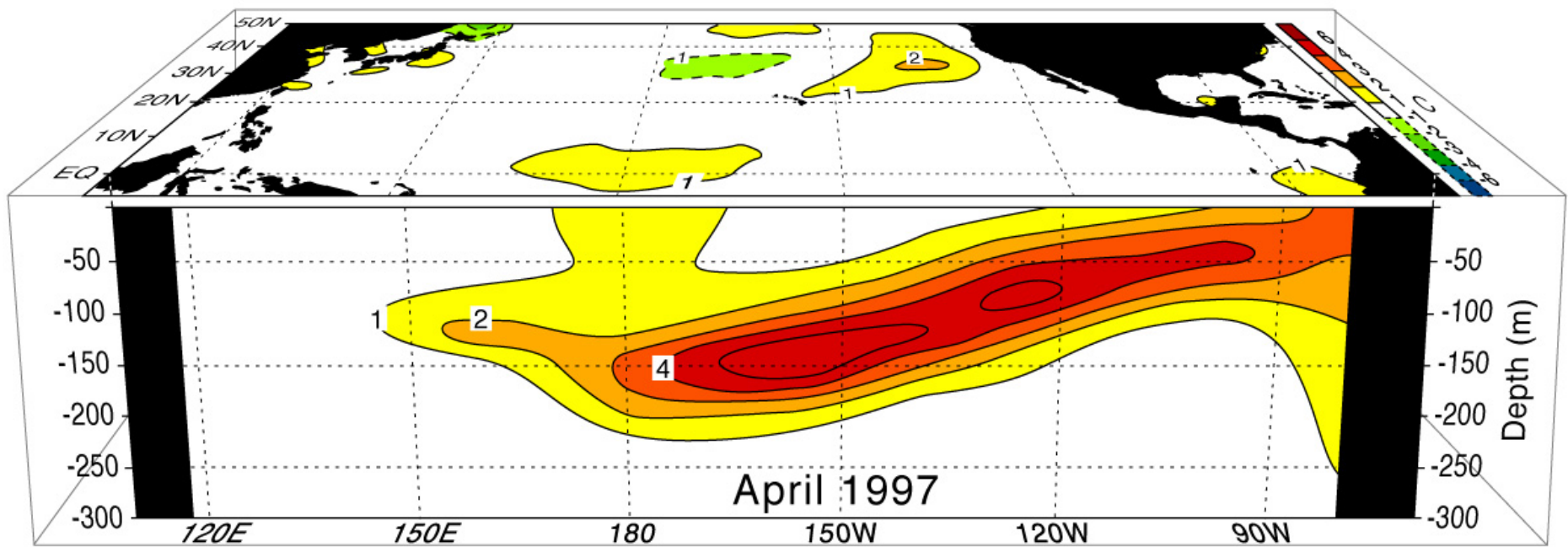


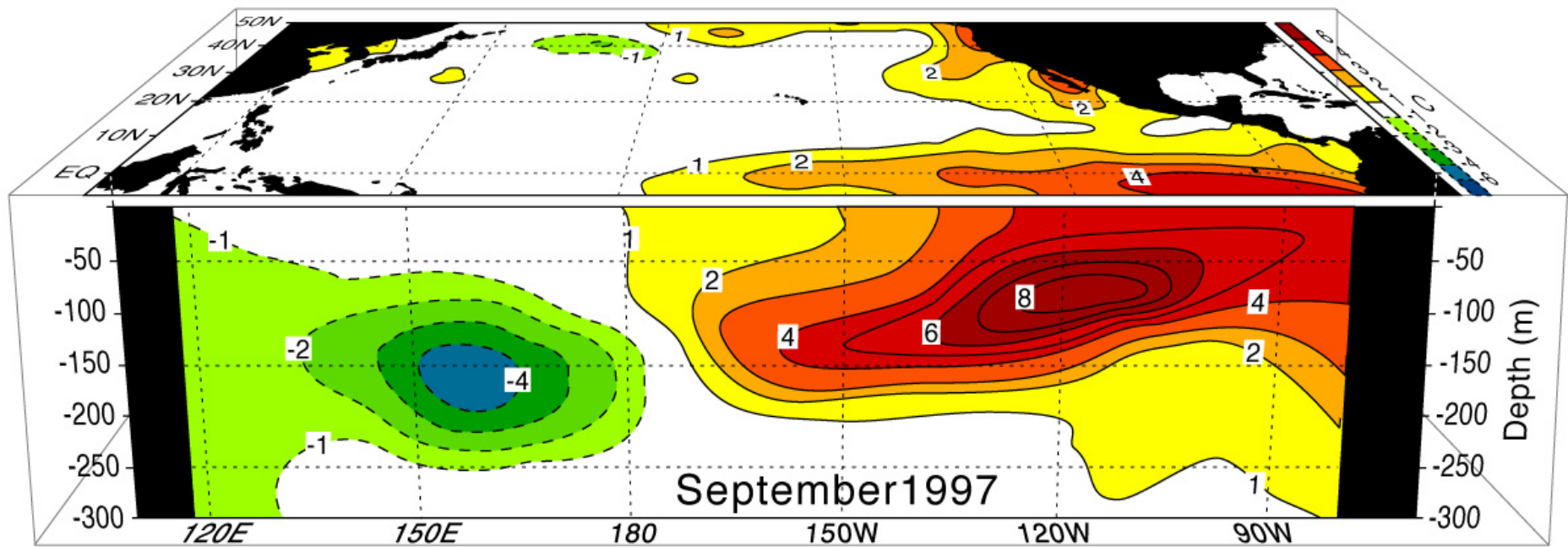
Evolution of the 1997-98 ENSO Event



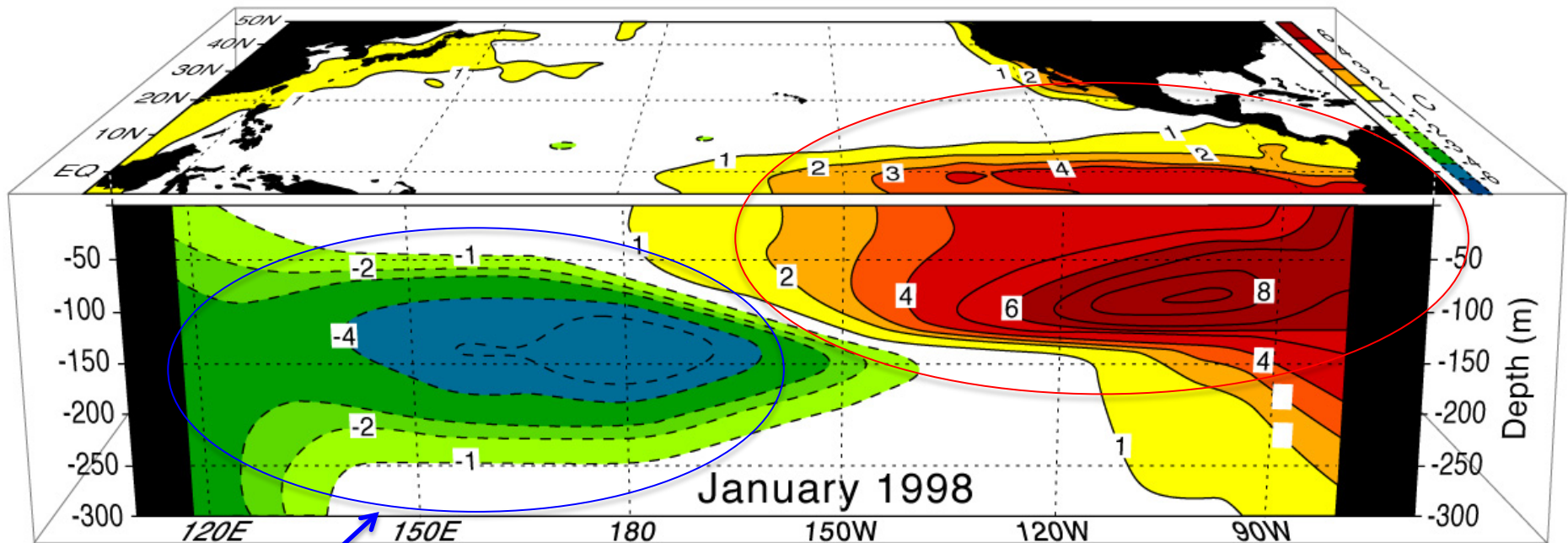
Warm Sub-Surface Temperature (Deeper Thermocline) Anomaly is the Precursor of the Coming Warm Event – Why We Can Predict



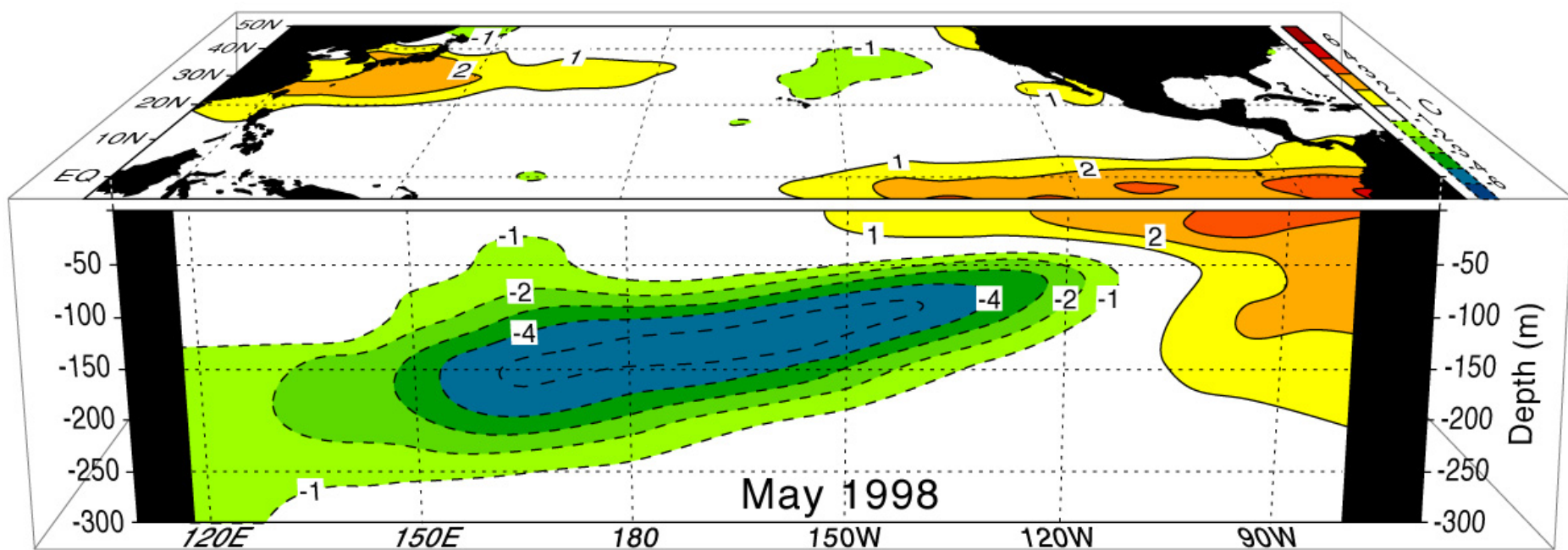


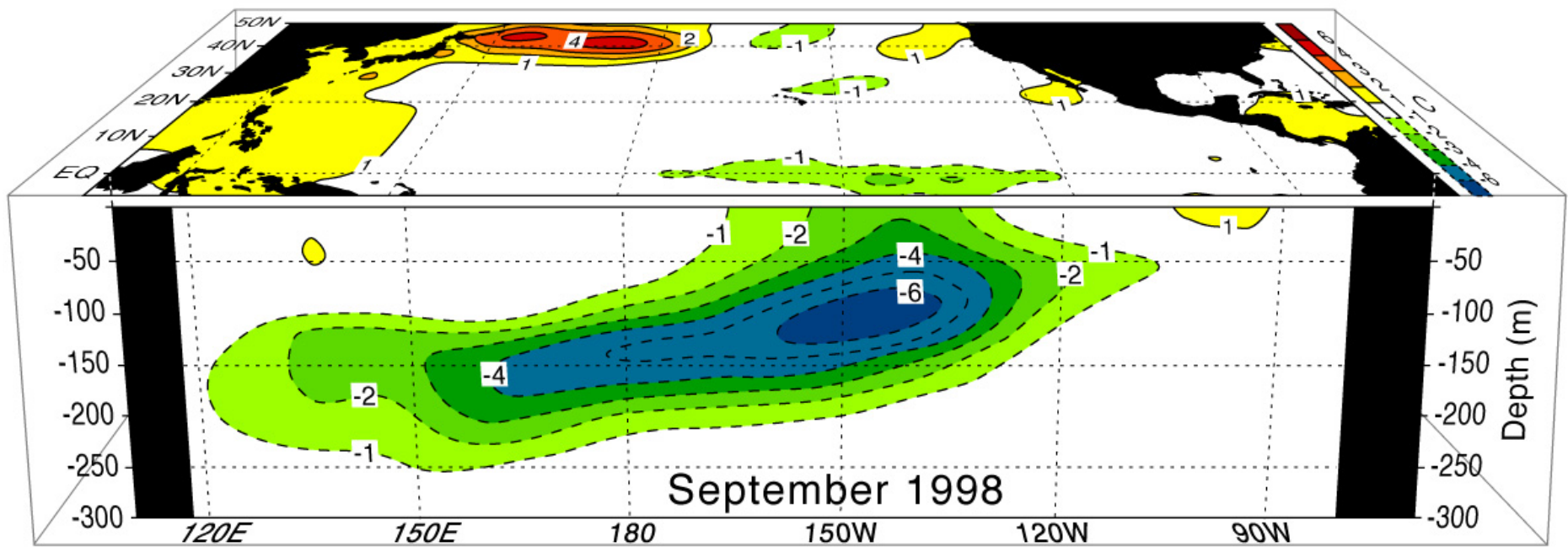


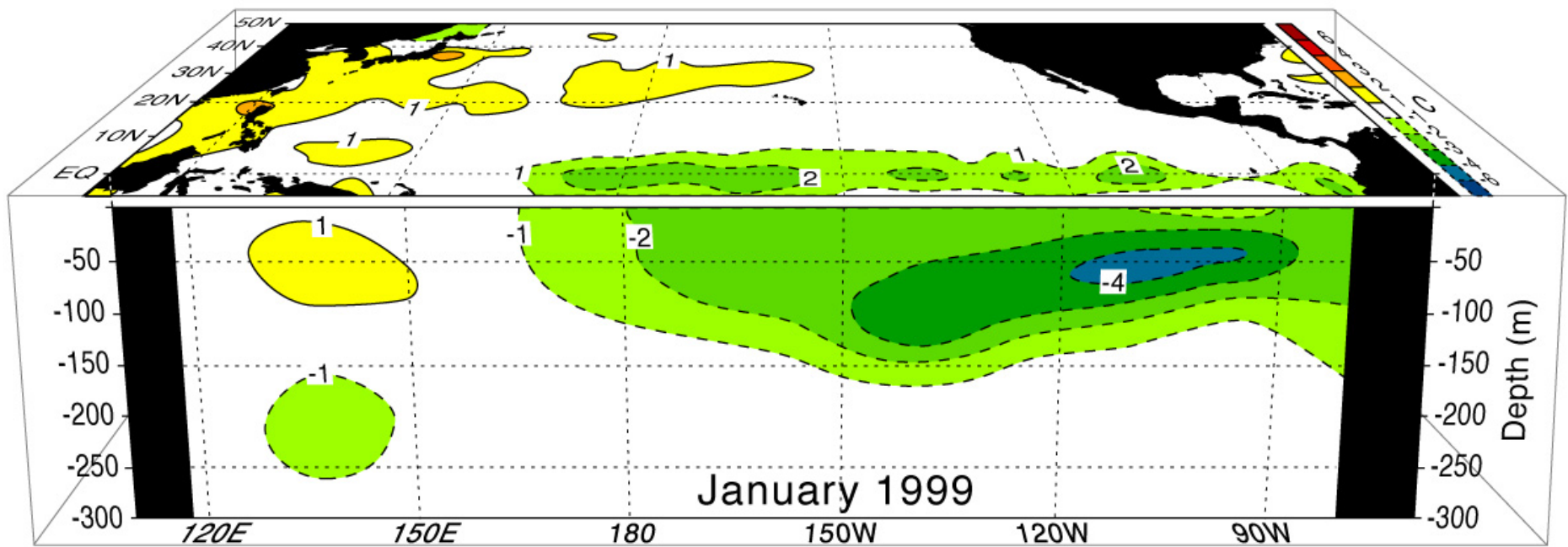
Mature Warm Event



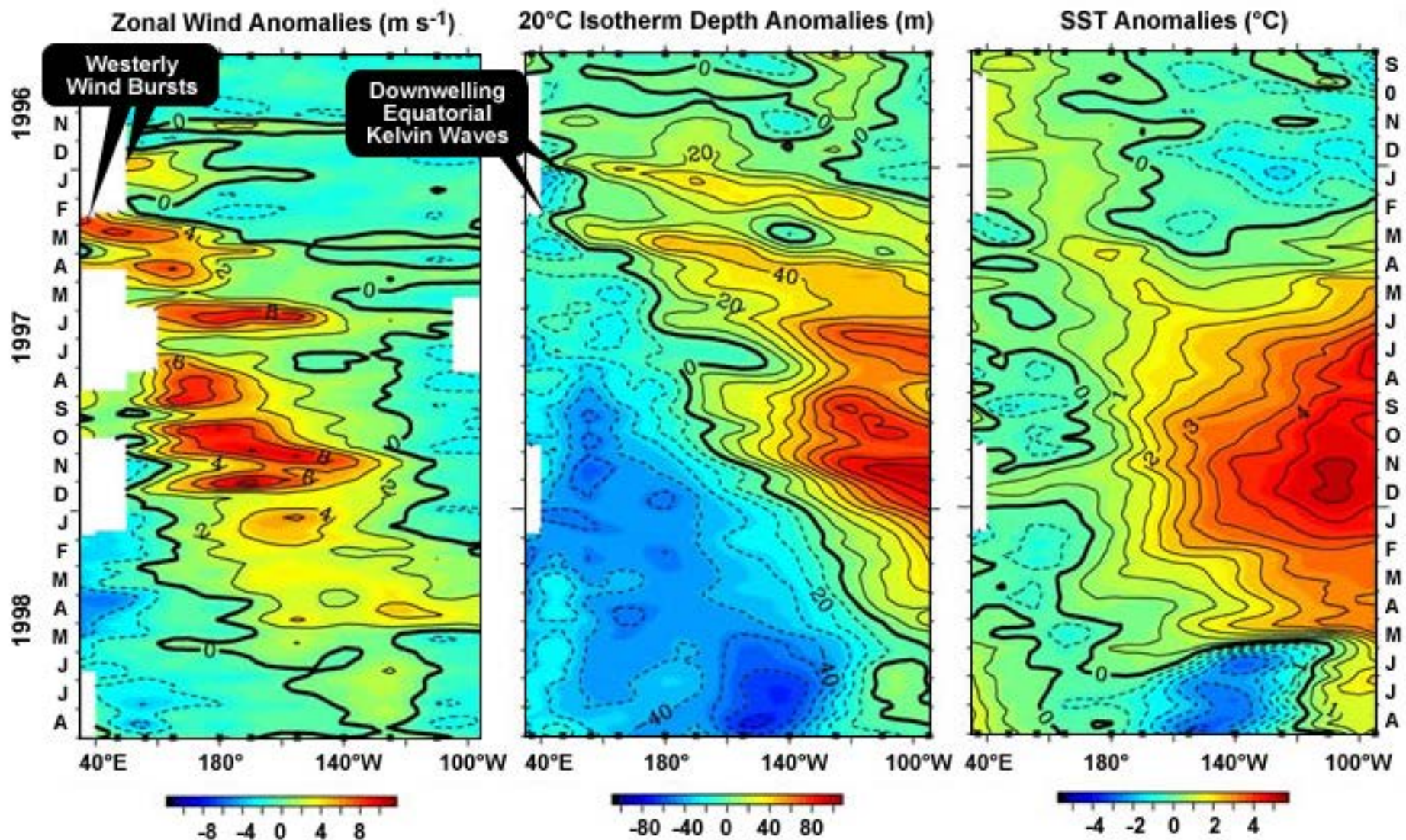
The Precursor of the Coming Cold Event





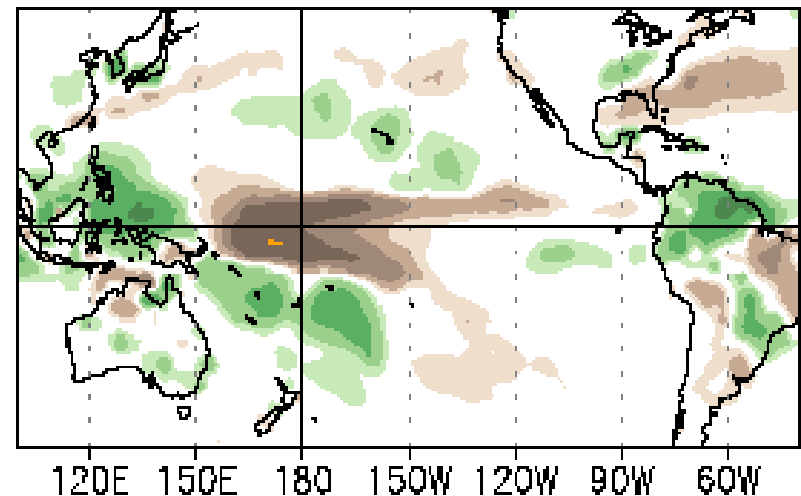
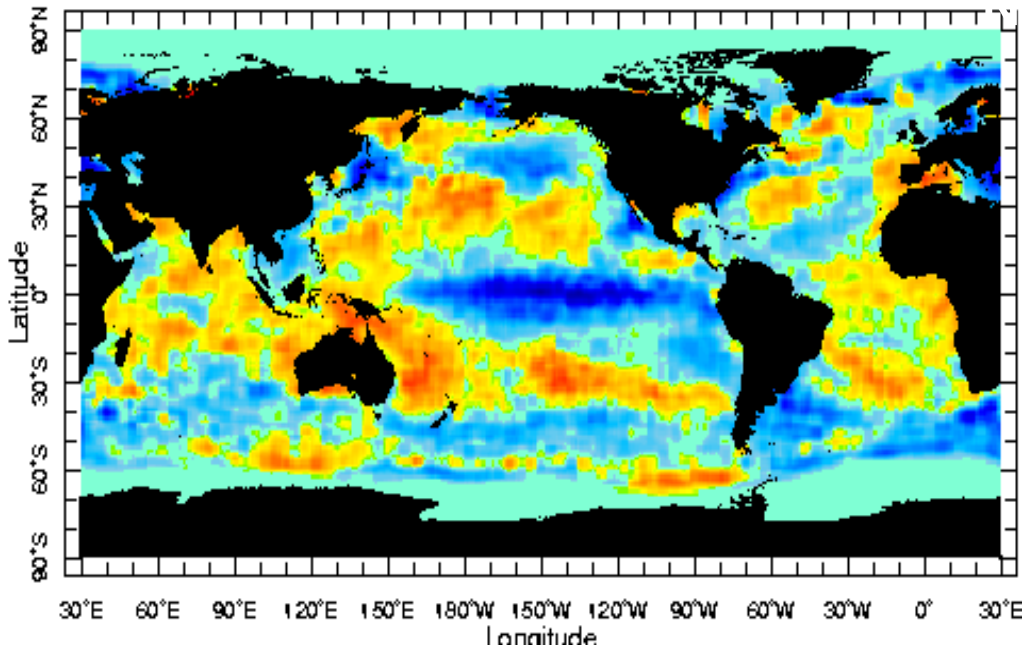
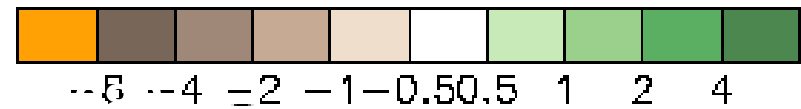
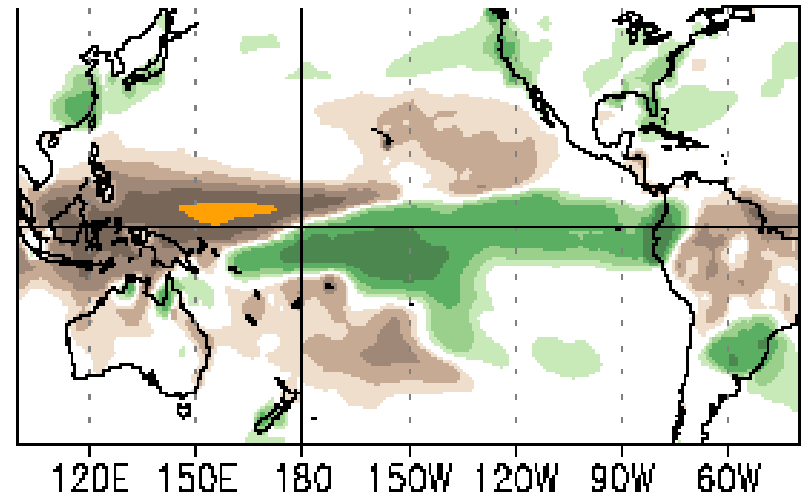
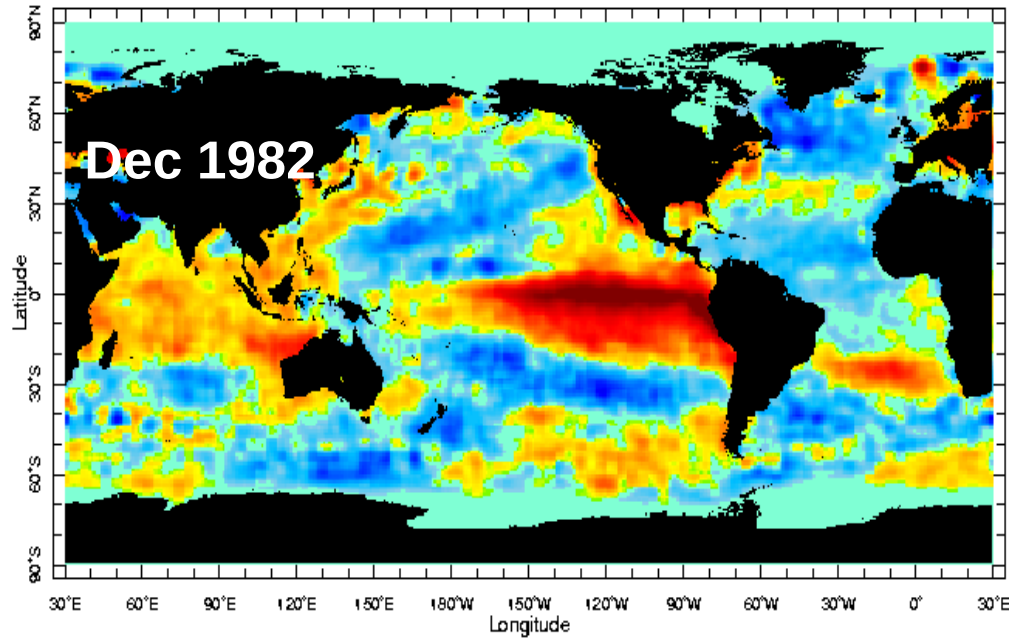


Evolution of the 1997-98 ENSO (2°S-2°N Averages)



Teleconnections

SST $\Rightarrow$ Rainfall



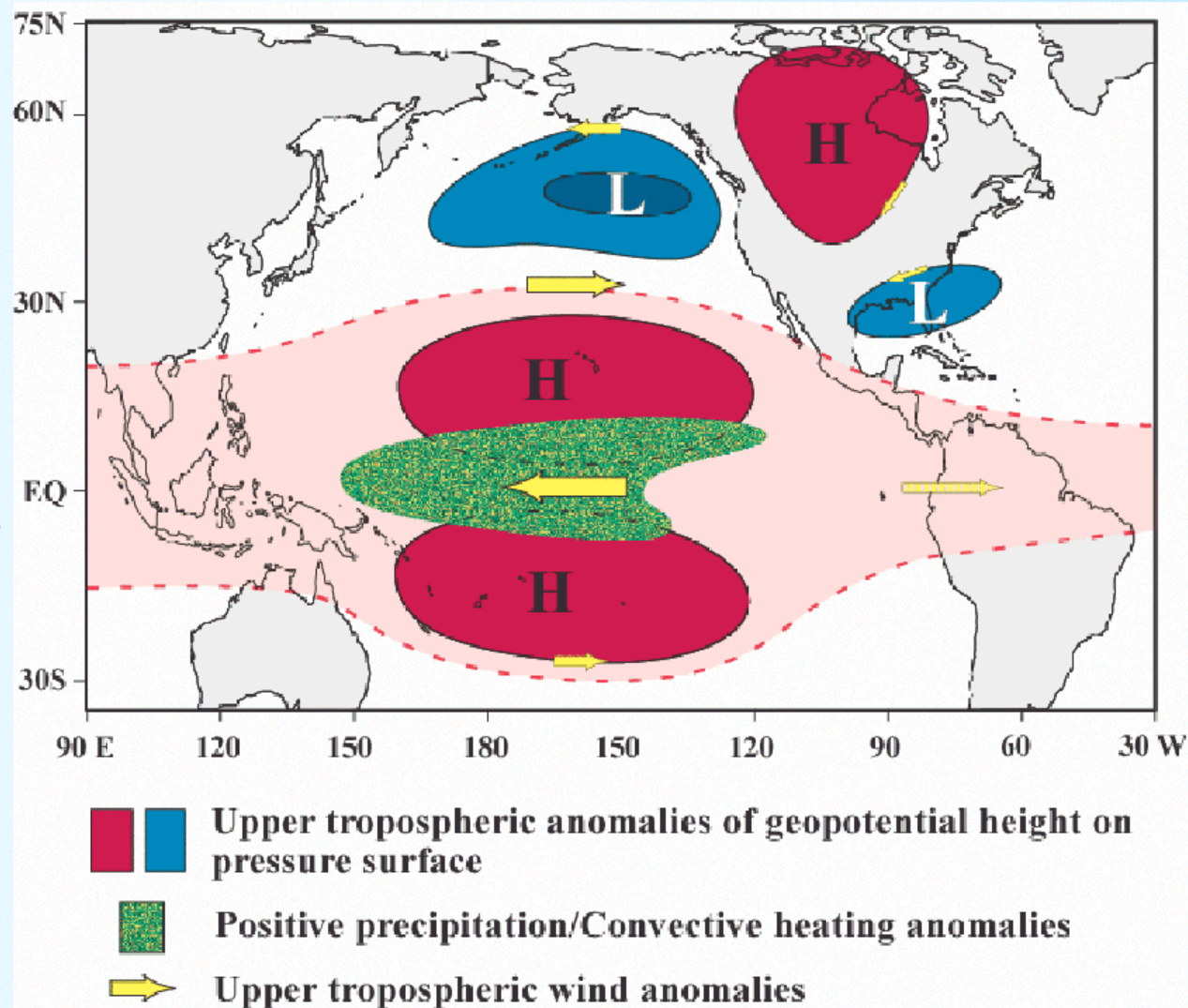
Pacific - North American sector

Response to El Niño

La Niña: opposite sign to a first approximation
(but weaker, esp. over N. America)

Mid-latitude response:
barotropic, same sign
through depth of
troposphere

Tropical response:
baroclinic, opposite sign
at low levels



Refs: J.M. Wallace et al 1998,
K. Trenberth et al 1998

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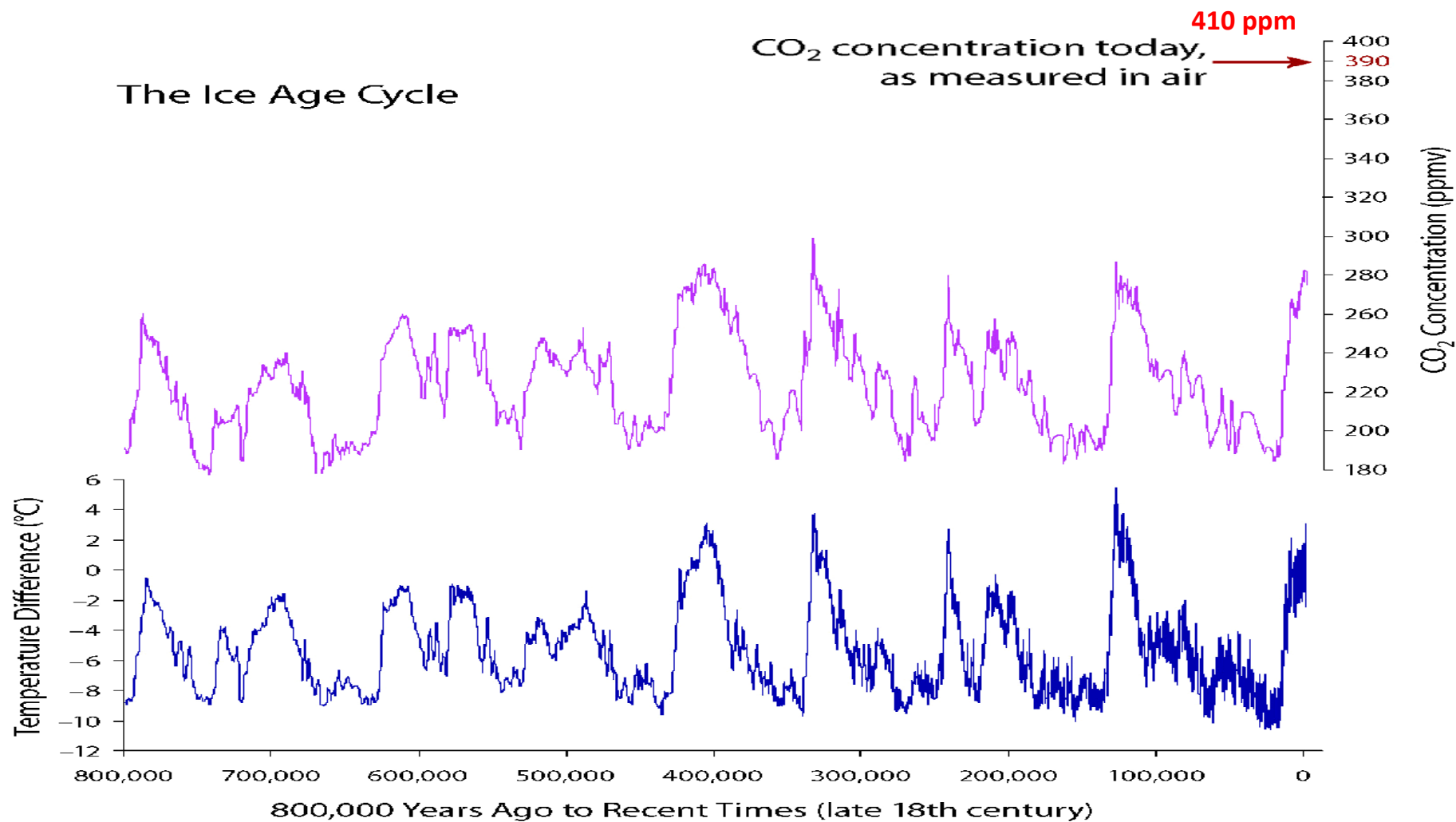
- Stationary and Transient Eddies

2) Large-Scale Tropics

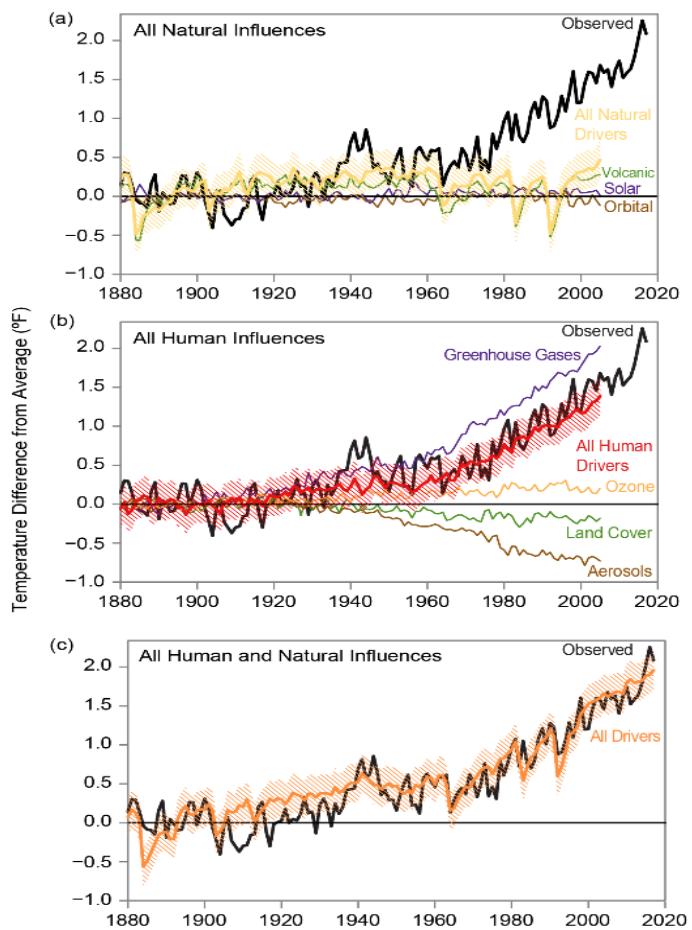
- ENSO

3) Climate Change

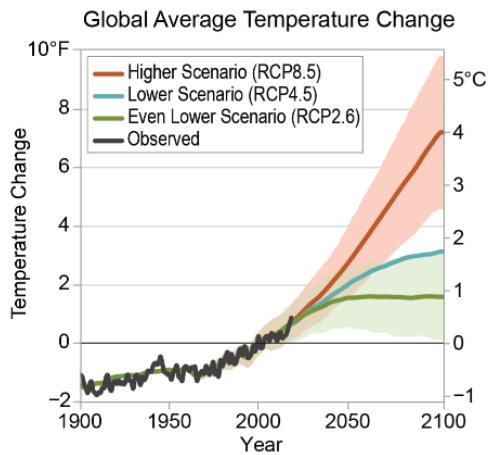
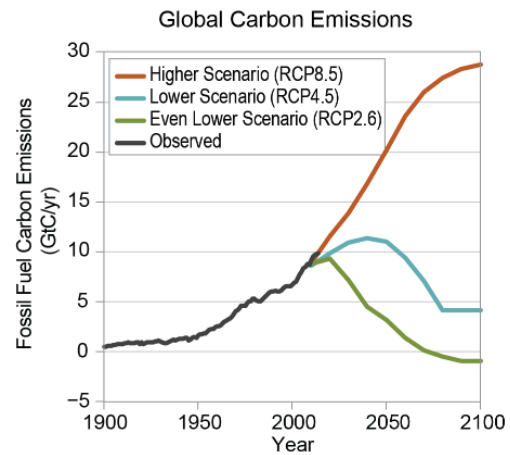
The Ice Age Cycle



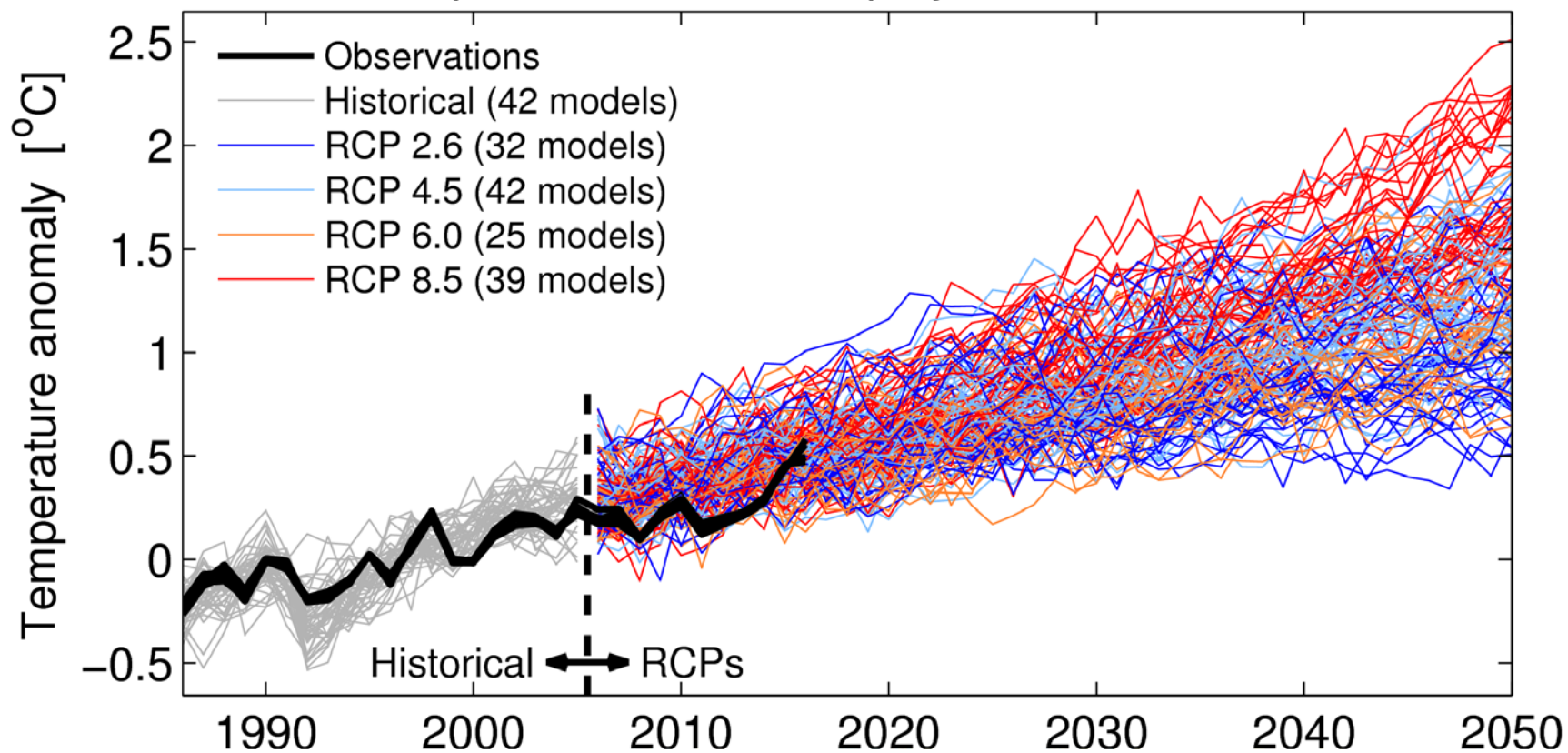
How We Understand Human Influence on Climate



Projections of Future Human Influence on Climate



Global mean temperature near-term projections relative to 1986–2005



Large-Scale Circulation: Three Big Ideas

1) Meridional Temperature and Momentum Transport (Mean Meridional Circulation)

- Stationary and Transient Eddies

2) Large-Scale Tropics

- ENSO

3) Climate Change

- Weaker Overturning Circulation